THE USE OF RANGE, BEHAVIOUR, NEAREST NEIGHBOUR DISTANCE AND FEATHER CONDITION OF COMMERCIAL FREE-RANGE LAYING HENS

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Abstract

This thesis is based on the evidence of the use of range by laying hens from two separate studies that were carried out on commercial flocks. The first study involved a direct observation of 6 flocks of laying hens whereas the second study was carried out on a single flock of laying hens using a still digital camera. Mapping of the outdoor range into three zones, namely; apron (0-10metres), enriched (10-50metres) and range (beyond 50metres), was carried out in both studies determine whether it influenced the distribution, behaviour, nearest neighbour distance (NND) and feather condition of the hens.

Based on the estimates of the total number of hens recorded outdoors, it was found that 14.5% of the hens used the range in the first study, with 6.0% of the hens seen in the apron, 4.8% in the enriched and the remaining 3.7% in the outer range zone. This ranging pattern was further confirmed by the quadrat head counts, where the hens used the apron most but showed a significant decrease in the use of other outdoor zones as distance increased from the shed ($p < 0.001$). The results of the two studies showed that range use peaked in the morning and decreased significantly in the afternoon ($p < 0.001$). Range use was found to increase significantly with age ($p < 0.001$) in the first study, although there was a significant decrease in the number of hens outside the shed as the flocks got larger ($p < 0.001$). The age effect reported in the six-flock study was complemented by the significant positive effect of the week of outdoor access on the ability of the hens to use the range ($p < 0.001$) in the single flock study. Range use increased as outdoor temperature rose in the six-flock study whereas increased outdoor temperature resulted in a decline in range use in the single flock study. NND of the hens was

measured in the six-flock study and was found to decrease significantly towards the shed ($p < 0.001$) and as the hens aged ($p < 0.001$). There was evidence that the use of distant and less crowded outdoor locations by the hens in the first study was associated with improved feather conditions.

The evidence presented in the two studies presented in this thesis showed that the hens were unevenly distributed in the range, with reduced hen density (hen/m^2) towards the outer range and that an improvement in the use of distant parts of the range may have beneficial effects on the hens.

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Key Words: Range, behaviour, outdoor, laying hens, apron, enriched, outer range, zone, flock, feather conditions.

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Dedication

I dedicate this work to my beautiful wife, Ifeoma and my lovely children, Ikenna and Kamsiyochukwu.

Acknowledgements

I am most grateful to Almighty God whose grace saw me through this work. I wish to also appreciate in a special way my brother Mr. Benedict Uchenna Chielo, who selflessly sponsored my PhD study and to my father, Late Mr. Nweke Chielo for being my true icon, even in death.

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Chapter 1

Introduction

The chicken (*Gallus gallus domesticus*) is a domesticated fowl and the type reared for egg production is referred to as the laying hen. Chickens have lifespan of up to 7 years and are known omnivores often found scratching the soil in search for seeds, insects, worms and small animals for food (Mills et al. 2010). Domestic chickens are known to be descendants of the Red Jungle fowl native to the south and eastern Asia (Johnsgard, 1986). Archaeological evidence has shown that chicken was domesticated about 8000 years ago (Nicol, 2015) and that it retained similar characteristics as their wild ancestors (Kruijt, 1964) which includes roaming of their immediate environment in search of food. Domestic fowls allowed to become feral have shown similar behaviours as the red jungle fowl (Duncan *et al*. 1978; McBride *et al*. 1969) and thus it is argued that the environmental requirements of the modern chickens are likely to be similar to that of their known ancestors. Red jungle fowls in feral state live in small groups of about 6 - 10 (Mills *et al*. 2010) and are also found to roost in groups of approximately five individuals (Collias and Collias, 1967). The group size seen in the feral condition is by far different from that of the commercially intensively flocks made up of large number of chickens (in thousands), housed in the cages or alternative housing systems. Commercial hens may or may not have access to the outdoor range thereby giving them limited environmental choices and preferences (Appleby and Hughes, 1991) that are usually associated with welfare problems e.g. increased fearfulness, increased bone weaknesses, increased bone fractures and decreased opportunities to perform many different behaviours (Appleby and Hughes, 1991; Jones, 1996; Mills and Wood-Gush, 1985; Knowles and Broom, 1990). Although these systems benefit from reduced cost of production, the impoverished nature of the rearing environment (with insufficient amount of enrichment resources or lack of it) has been blamed for the poor welfare condition of the resident animals (Brambell, 1965). Also, due to the group composition of commercial laying flocks (made up of only female hens), they are less likely to develop mixed social groups, consisting of hens of different ages and sexes.

The Food and Agricultural Organization estimated that in 2010, the global egg industry was made up of over 6.5 billion laying hens and produced over 6 billion table eggs annually with production expected to rise in the subsequent years (FAOstat, 2013). Asia (4.2 billion layers) was the largest producer followed by America (1.05 billion hens), Europe (765 million hens), Africa (509 million hens) and Oceania (18 million hens) respectively (FAOstat, 2013). China was the largest egg producer (production estimated to be up to 37% of the total global egg output) alongside other significant producers like the United States of America, India, Japan, Mexico, Russia, Brazil, Indonesia, Ukraine and France (FAOstat, 2013).

There were over 360 million laying hens raised in the 27 European Union member states in 2011 which produced a total output of 6.9 million tonnes of useable eggs / egg products per annum (European Commission, 2011). Spain produced 13.2% of the total output alongside other key players like France (12.5%), Germany (11.1%), Italy (10.2%), Netherlands (10.0%), United Kingdom (9.9%) and Poland (8.9%), accounting for ¾ of the European Union egg output in 2011 (European Commission, 2011).

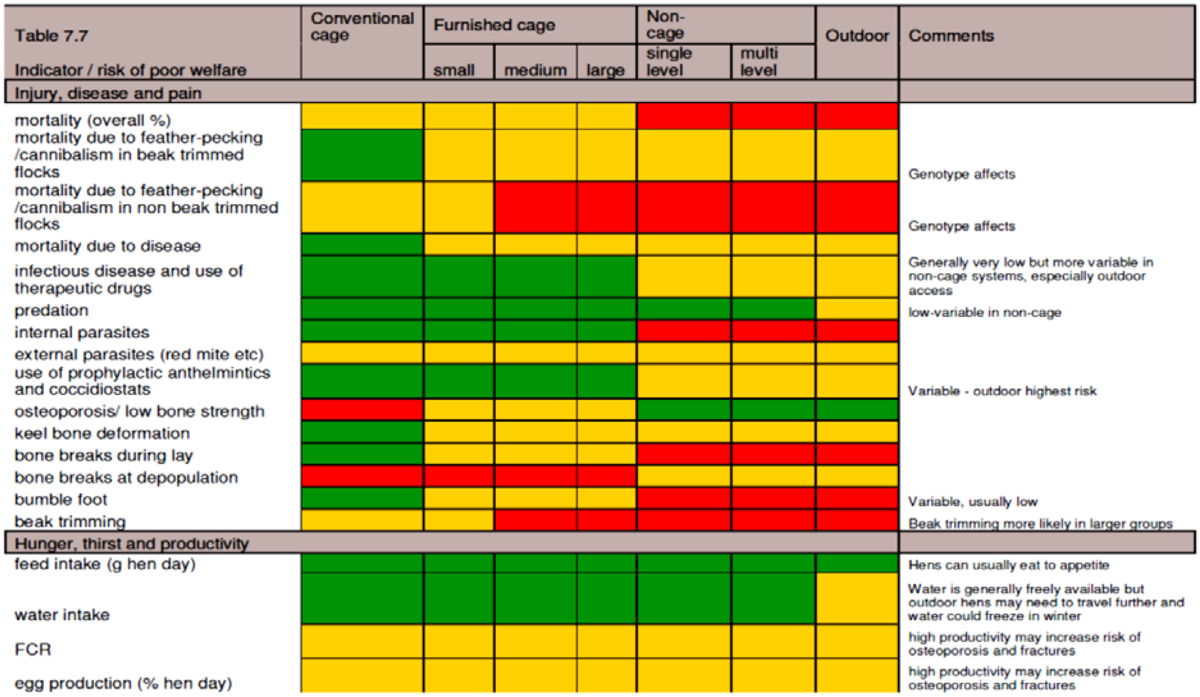
In 2012, there were estimated 34 million laying hens raised in the UK, which produced over 9 billion eggs (Defra, 2012). The British Egg Information Service estimated that the UK egg industry produced over 10 billion eggs, imported a little under 2 billion eggs and exported 118 million eggs, to give 85% sufficiency in egg production in 2016 (BEIC, 2016). In total, they estimated that the UK egg consumption for 2016 was over 12 billion eggs with over 34 million eggs eaten every day at 194 per capita.

Animal welfare is a complex subject that is of increasing importance to the farmers, consumers, veterinarians, politicians and welfare advocates (Hewson, 2003) and means different things to different authors. There are different approaches to animal welfare which determine the area of emphasis definitions by the authors (e.g. Broom, 1986; Brambell Report, 1965; Hughes, 1976; Dawkins, 1990; Spruijt *et al*. 2001). Most definitions of animal welfare include the physical, physiological and psychological components (e.g. Hughes, 1976; Mills *et al*. 2010) which largely emphasised that animals are sentient beings and that their welfare state is determined by their overall well-being. Broom (1986) described the welfare state of an animal as its attempts to cope with its environment and further argued that welfare should be measured for each individual and not on group basis. This is because the welfare of some individual animals in a group may be good whereas other members of the group may have difficulties coping with their environment. The framework widely used in measuring the welfare outcome or risk to welfare of laying hens in any given management system is the 'Five Freedoms of Animal Welfare' (FAWC, 1979; Duncan, 2001; LayWel, 2004). The Five Freedoms were outlined by the UK's Farm Animal Welfare Council in 1979 (FAWC, 1979) and updated in 2012 (FAWC, 2012). They were based on the advances made in scientific knowledge and husbandry practices following the Brambell Committee report in 1965 (Brambell, 1965) and according to McCausland (2014), are not actually treated as 'animal rights' but are used as an established framework for the protection of the interests of animals under human care. The five freedoms approach to animal welfare does not just cover the health (freedom from pain, injury and disease) aspect of an animal's well- being but also the mental state of the animal (e.g. freedom from fear and distress). Other aspects such as the comfort, nutritional status and the ability of the animal to express its species specific natural behaviour are part of the core welfare requirement of the animals. The five freedoms are outlined below;

1. Freedom from hunger and thirst
2. Freedom from discomfort
3. Freedom from pain, injury or disease
4. Freedom to express normal behaviour
5. Freedom from fear and distress

These freedoms represent a set of conditions that captive animals should receive to ensure that they have good welfare e.g. to maintain good welfare for laying hens, they should; be provided with enough clean fresh water and right type and amount of food to keep them fit and healthy; have the right type of environment including shelter and a comfortable place to rest; be prevented from getting ill or injured and also ensure that they are diagnosed and treated rapidly if they do; have enough space, adequate facilities and the company of conspecifics; have living conditions and treatments that are void of any mental suffering. Meeting these conditions for laying hen would ensure that they are not only physically and physiologically well but are also mentally sound and based on this, the UK's RSPCA and some of the major worlds welfare organizations e.g. Australia's RSPCA, Animal Welfare Institute USA, World Organization for Animal Health, World Society for Protection of Animals (WSPA) and International Fund for Animal Welfare (IFAW) have adopted this framework as a means of assessing and protecting animal welfare.

The LayWel project, commissioned by the European Union, with the University of Bristol as a partner, examined the overall strengths and weaknesses of different commercial housing systems for laying hens based on the five freedoms of animal welfare and outlined the overall welfare impact of each housing system using a 'traffic light' approach (LayWel, 2004). The study compared the welfare outcomes of the laying hens housed in the conventional cages, furnished (small, medium and large) cages, aviary (single and multi-level) and outdoor systems and their relative risks to good welfare using the three traffic colour codes i.e. green, orange and red. Each traffic colour code represented their potential risk to good welfare, with green colour used to indicate good or satisfactory welfare or performance, orange colour indicated medium risk to welfare whereas red colour represented a high risk of poor welfare to the hens. However, they noted that the colour codes stated above only suggested the probability of good or poor welfare of the system rather than a definite state of optimal or sub-optimal welfare condition for the hens. The project utilized a wide range of welfare indicators (e.g. mortality, fearfulness, immune function, stress response, plumage condition, egg production, feed intake, predation, bone breaks during depopulation, water intake, keel bone deformation, internal and external parasites, bumble foot, beak trimming, nesting behaviour, use of dust bath and behavioural restriction) in assessing the welfare condition of the hens and found that battery cages offered greater welfare benefits (green colour) to the hens in some key areas compared to the alternative systems. They reported that the caged systems resulted in lower overall mortality and mortality due to feather and cannibalism and there was also evidence of reduced incidence of diseases and parasitic infections in caged system compared to the alternative systems. However, hens in alternative systems showed evidence of greater bone strength, greater foraging behaviour and reduced behavioural restriction compared to the conventional cages (Table 1). They concluded that all the systems used in egg production have the potential to provide good welfare for the laying hens except the conventional cages which fail to provide adequate space and opportunities for the hens to fulfil their behavioural priorities and preferences e.g. hens need to perform nesting, perching, foraging and dust bathing behaviours that are not seen in cages (Baxter, 1994). Other studies have also identified the critical welfare problems associated with the small sized, barren conventional cages, usually arranged in the sheds on top of each other in rows (Council of Europe, 1986) as reduced opportunities to exercise, reduced behavioural opportunities e.g. flying, running, wing flapping and nesting (Dawkins and Hardie, 1989; Hughes *et al.* 1989; Nicol, 1987; Van Liere, 1992; Blokhuis and Metz, 1995) and increased foot lesions (Duncan, 2001; Cooper and Albentosa, 2003; Weeks and Nicol, 2006). These welfare issues existed despite the welfare benefits that are derivable in the caged system e.g. better hygiene due to lower disease incidence, reduced social conflicts due to smaller group size, improved management, eradication of litter problems, improved working environment and reduced production costs (Duncan, 2001). Several studies have investigated the behavioural preferences of the laying hens and suggested that they have strong desire to perform certain behaviours e.g. foraging (Nicol and Guilford, 1991; Cooper and Appleby, 1995; 2003; Smith *et al*. 1990) known to be controlled by internal motivations e.g. hormones (Etches, 1990) and that the need to perform them is strong in any given environment (Duncan, 1998). It is important to note that laying hens may suffer if they are not allowed to perform these important behaviours (Cooper and Albentosa, 2003, Weeks and Nicol, 2006).



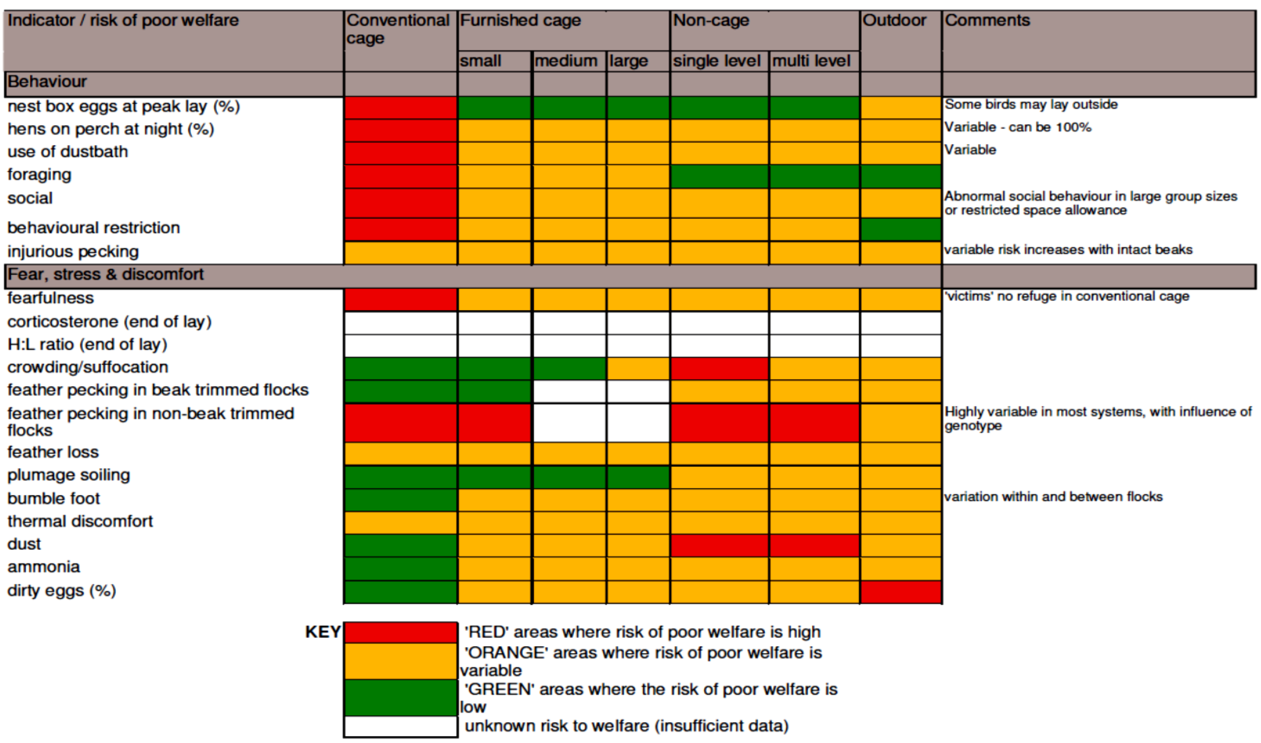


Table 1.0. Showing the welfare risk assessment of different housing systems used in keeping laying hens (Source; Laywel, 2004). It shows that the welfare risk of the battery cages to the hens laying was low in many aspects e.g. mortality and diseases but high in the behavioural measures e.g. fearfulness and behavioural restrictions.

The Happy Egg system used in the current studies is a brand of free-range system introduced by the Noble Foods in January 2009 (The Happy Egg Company, 2016), which provides additional leafy trees, more space, specifically designed activity kits e.g. perches, mini sheds, climbing frames and dust baths and the dedicated farmers looking after the laying flocks. The hens leave their sheds at will through the pop-holes (usually open between 9am to 6pm) located on the sides of the shed to roam, forage and explore the fields for other resources e.g. insects and worms.
Provision of outdoor roaming space vegetative cover (under which the hens can seek protection from predators and bad weather conditions) in the outdoor range is a legal requirement for laying hens kept in free-range system, as outlined by the European Union Council Directive 1999/74/EC. The council directive requires that the free-range laying hens must be provided with at least $4m^2$ of land space per bird in the outdoor run (or 2500 hens per hectare) and that the range extends no more than 150m from the pop-hole unless additional enrichments or shelters are provided in the range. The hens kept in this system have greater opportunities to engage in all kinds of behaviour e.g. foraging, nesting and being that they have access to large expanse of land, they are also able to gain fitness through exercising and have greater opportunities to avoid aggressive flock mates.

Free-range egg production has become increasingly popular in the UK, in line with the increasing consumer interest in welfare friendly products and the banning of conventional battery cages across the European Union states from January 2012 (EC Directive 1999/74/EC). The ban did not include the use of enriched (furnished) cages which offer additional space and enrichment resources e.g. perches and dust bathing facilities to the hens compared to the traditional cages and was based on the growing concern for the welfare of farmed animals in EU and also on the scientific evidence obtained from studies of caged hens (EU Scientific Veterinary Committee, 1996).

One of the major problems with the free-range system is that most of the hens stay in the sheds and when they leave the sheds, they usually prefer to stay in the immediate area surrounding the shed (Cooper and Hodges, 2010). They are also reported to be unevenly distributed in the range area with relatively few birds (less than 15%) found to venture far from the sheds especially in large flocks (Bubier and Bradshaw, 1998; Dawkins *et al.* 2003; Cooper and Hodges, 2010; Hegelund *et al.* 2005; Hirt *et al*. 2000). The low turn-out of the hens in the outdoor area constituted poor use of range (Nagle and Glatz, 2012; Pettersson *et al*. 2016) and has been found to result in greater incidence of feather pecking, cannibalism and parasitic fouling of pasture by the hens (Appleby *et al*. 1992; Bubier and Bradshaw 1998; Jones 1997). Pettersson *et al*. (2016) described poor range use in free-range laying hens as the proportion of hens in the range not exceeding 50% of the total flock and this is based on the evidence derived from studies carried out on outdoor use by the hens (e.g. Bubier and Bradshaw, 1998; Hirt *et al*. 2000; Hegelund *et al.* 2005; Nagle and Glatz, 2012; Sherwin *et al*. 2013; Gilani *et al*. 2014). Similar outdoor use pattern was reported in free-range broilers, with about 15% of the total flock found to use the range at any one time (Dawkins *et al*. 2003). However, the problem of poor range use can be solved by enriching the range environment with resources valued by the hens e.g. shades, forages and shelter belts, to effectively attract more hens into the range (Nicol *et al.* 2003; Bestman and Wagenaar, 2003; Hegelund *et al.* 2005; Zeltner and Hirt, 2008a; Nagle and Glatz, 2012).

Although the use of outdoor space by free-range laying hens has been reported to expose them to a number of risks e.g. increased risk of predation and parasitic infections (e.g. Moberly *et al*. 2004), it is also found to offer them a number benefits to their welfare e.g. greater choice of locations, greater environmental stimuli, exposure to natural daylight, greater foraging opportunities, increased hunting and exploratory behaviours, reduced feather pecking and cannibalism, enhanced bone strength, reduced indoor stocking density (number of hens/m^2 of the shed), improved body/feather conditions and reduced stress (Nicol *et al.* 2003; Knierim, 2006; Richards *et al*. 2011; Molee *et al*. 2011; Rodriguez and Estevez, 2016; Blokhuis and Arkes, 1984; Blokhuis 1986; Hughes and Duncan, 1972; Simonsen *et al*, 1980; Huber-Eicher and Wechsler, 1998; Nørgaard-Nielsen *et al*. 1993; Wechsler and Huber-Eicher 1998; Green *et al*. 2000).

However, the potential benefits of the outdoor run to laying hens in free-range system (stated above) is only achievable when the hens actually make use of the range and based on this, the study of range use pattern by free-range laying hens is an important approach towards ensuring good welfare. There are possibilities that more hens will be encouraged to leave their sheds if the factors found to limit range use in flocks laying hens e.g. keel fracture, flock size, stocking density, pop hole size, pop hole number and design, house design, climatic conditions, range design, absence of cover, hen genotype and prior experience in the range (Keeling *et al*. 1988; Grigor *et al*. 1995a; Bestman and Wagenaar, 2003; Nicol *et al*. 2003; Mahboub *et al*. 2004, Hegelund *et al*. 2005; Richards *et al*. 2011; 2012; Nasr *et al*. 2012; Nagle and Glatz, 2012; Gilani *et al*. 2014; Sherwin *et al*. 2013) are addressed or improved (Nicol *et al.* 2003; Bestman and Wagenaar, 2003; Hegelund *et al.* 2005; Zeltner and Hirt, 2008b; Nagle and Glatz, 2012).

Aims and objectives of the thesis

The aim of this thesis was to study the use of outdoor range by laying hens in commercial conditions in 2 large studies presented in chapters 4 and 7 of this thesis.

In the first study, a total of six flocks of free-range laying hen flocks were used and the overall proportion of range use was measured alongside hen distribution in the quadrats, nearest neighbour distances, feather condition measures and behaviours of the hens in the range using quadrat, transect and head counting techniques.

The second study explored the temporal changes in the use of range by the hens from the first day of range access for a total of 15-weeks using the weekly data collected from a single flock of free-range laying hens.

The specific aims of the six flock study were to;

- Investigate the overall proportion of the hens found in the range using a general head count approach
- Explore the distribution of the hens between across the main areas of the range i.e. the apron, enriched and outer range areas using quadrat, transect and head count techniques
- Determine the behaviours performed by the hens in the range and estimate their relative proportion in the apron, enriched and outer range zones

- Explore the impact of time of the day on the use of range by directly observing the hens every hour between 10am and 2pm during each visit day
- Assess the feather conditions of the hens in the different outdoor areas using a 5-point scale scoring system and determine if the location of the hens in the range was associated with changes in their feather cover
- Assess the effect of location on the nearest neighbour distances (NND) of the hens in the range
- Assess the effect of flock size (number of hens in a flock), age and strain on the behaviour of the hens and their ability to use the range

The main aims of the single flock study were to;

- Assess if the experience of the hens in the range had any effect on their ability to range by observing the hens weekly from release for 15 weeks using a digital camera
- Explore the impact of time of the day on the use of range by observing the hens every hour between 9am and 2pm each visit day
- Examine the impact of temperature, relative humidity and wind speed on the use of range

Chapter 2

The use of outdoor space, behaviour and environmental enrichment for free-range laying hens

In this chapter, the different housing systems used in keeping laying hens are discussed alongside an exploration of the advantages and disadvantages of each system to the welfare state of the laying hens are also explored. The behavioural profile and the value of each of the behaviours to the hens as well as the possible welfare implications of depriving them of the chances of performing such behaviours are also discussed. Here the difference between the provided space (as specified by the law) and the actual amount of space required by the hens for performing different behaviours are also described. The details of the relevance, goals, approaches and types of environmental enrichment to captive animals are also discussed.

Evidence from the existing literature suggested that though there is no ideal husbandry system for keeping laying hens, the battery caged system appeared to cause severe behaviour limitations to the hens (e.g. Laywel, 2004). Eggs produced in alternative systems are mostly preferred by consumers because they are thought to be produced in more welfare friendly environment compared to the battery cages. The use of range by free-range laying hens is influenced by different factors e.g. temperature, RH, rainfall, wind speed, wind direction, amount of cover in the range, pop hole availability, flock size, indoor/outdoor stocking density, size of the shed, with evidence of improved range use when their environments are enriched.

Range environment can be enriched by providing resources e.g. tree covers, hay, shelter belts, shades, hedges, artificial structures and forages, in the range.

The laying hens and husbandry systems

Laying hens are egg type chickens and are kept in many different housing systems and the system in use determines the nature of environmental resources provided, accessibility for the carers and the degree of freedom allowed to the hens. As a minimum requirement, all the housing systems (conventional cages, furnished cages, aviary, free-range) must provide the hens with the basic physical or biological needs e.g. food, water, light, good air quality, space and hygienic environment to promote productivity, survival, good health and welfare (AVMA, 2012; Cooper and Albentosa, 2003; Weeks and Nicol, 2006). Although no system is ideal for egg production, they all must ensure that the major requirements of good animal welfare are met e.g. protection from predators, injuries and diseases, promotion of expression of normal behaviours. The housing systems for laying hens (conventional cages, furnished cages, barns and free-range systems) are discussed below.

Traditional or conventional battery cage system

The conventional cages are usually made of metal wires, with the arrangement of identical cages in column and rows and sharing common walls dividing them. They are usually operated from the outside and the poultry attendants do not need to enter the cages to care for the birds. Conventional cages have been heavily criticized for their poor vertical and horizontal space allowance for the hens

(RSPCA, 2016). A resting, medium sized unconstrained hybrid bird will occupy 600 cm^2 of space and this is expected to increase during activities (Bogner *et al*. 1979; Dawkins and Hardie, 1989; Freeman, 1983) and when compared to 550 cm^2 per/bird allowance in battery cages, it is clearly insufficient to support expression of most natural behaviours e.g. walking, stretching, wing flapping, running and flying. Also, the cage environment lacks enrichment resources such as perches, nest boxes and litter substrates.

Experiments have shown that hens have strong affinity for these resources and can work hard at pushing a weighted door to access them (Cooper and Albentosa, 2003; Weeks and Nicol, 2006). In the cage environment where these treasured resources are absent, the hens may suffer deprivation and this has the potential to impact their welfare negatively. Movement of hens in the cages is limited and this can result in poor exercising of the bones, hence the poor bone strength of caged hens (Laywel, 2004). However, this has been contradicted by the findings of Gregory *et al*. (1990) which reported that caged hens recorded only 5% of previous bone cracks compared with 25% from non-caged hens. They also found that the caged hens had greater incidence of recent broken bones and there was a reduced risk of collision in the cages compared to the perchery and free-range systems. The possible reason for the greater proportion of the laying hens with cracked bones was the use of perches in alternative systems (Sandilands *et al*. 2009). Even though the hens in non-caged systems exercise more and develop stronger bones, they also made use of the provided perches, which may have resulted in greater bone cracks.

Furnished or enriched cage system

The European Union Council Directive 1999/74/EC banned the use of battery cages in the EU countries from January 2012 but this ban did not include use of furnished cages after this date. The term furnished cage implies that the hens are provided with additional space (750cm^2/hen) and enrichment resources in the cage environment. The enrichment resources include perches, nest boxes, litter, claw shortening devices and providing these in cages means that the cage environment is furnished but this may not imply that the cage is enriched. Furnished cages facilitate better rearing and management of small groups of hens in hygienically improved conditions (Appleby and Hughes, 1991; Cunningham and Mauldin, 1996) and it is reasonable to refer to them as enriched cages because they provide additional resources (absent from battery cages) that encourage the hens to perform a range of normal behaviours e.g. exploratory, foraging, dust bathing and comfort behaviours. Though the furnished cage offers greater behavioural allowance due to the greater space allowance, the space may still be insufficient and may limit some behaviours e.g. flying and full wing flapping (Appleby *et al*. 2002).

B**arn or aviary system**

The most distinguishing factor between the barn and free-range system is the absence of outdoor area in the barn system. The hens kept in the barns usually spend their entire production cycle indoors, without any access to the outdoor area. In the barn system, the floor area may be fully or partially covered with litter and/or perforated floors. Barn and aviary systems are similar in most aspects except that the barn system is made up of single-level floor whereas aviaries are multi-level platforms. Litter materials are provided for the hens to encourage foraging and dust bathing activities. This system offers a number of advantages in the form of improved bone strength associated with increased movements, better feather condition, reduced risk disease transmission from wild birds and other animals, reduced risk of feather pecking, greater range of behavioural expression, protection from predators and adverse environmental conditions, decreased fearfulness (e.g. Knowles and Broom, 1990; Gregory *at al*. 1991; Hansen et al. 1993; Tanaka and Hurnik, 1992). A comparative study of the welfare and productivity of hens in barn and caged systems has been reported (Barnett, 1999). The study measured the stress level, immunology, feather condition, foot condition, claw length and bone strength as well as the body weight, egg production and egg quality of the hens in the two systems and found that barn hens had greater bone strength, better feather condition and cover. The barn hens were found to show greater parasite burdens and higher stress level, lower egg production, lower egg weight, reduced body weight, high incidence of floor eggs and greater microbial contamination of the eggs in comparison to their caged counterparts. However, Thomas and Ravindran (2005) reported higher mortality in barn layer hens and did not find any difference in the egg weight between barn and cage hens.

Free-range system

In free-range systems, there is a shed provided for the hens with access to the outdoor area. The hens are provided with sufficient outdoor space to enable them explore, get stimulated and opportunities to meet their behavioural needs (Duncan *et al*. 1998; Weeks and Nicol, 2006). The hens are usually allowed free daytime access to the range through the pop holes located on the sides of the shed and are able to choose locations that meet their needs e.g. location that can allow them engage in the desired activity at any point in time. The outdoor area is usually made up of enrichment resources such as perches, cover trees, mini sheds, grasses and open loose soil and these resources enable the hens to roam, explore, run, forage, fly, play, wing-flap, dust bath, and stretch at will. One of the major problem with this system is that the turn out of the hens in the range is usually low and that majority of the hens that use the range are found around the sheds and drops further as the distance from the shed increases (e.g. Appleby and Hughes, 1991; Bubier and Bradshaw, 1998; Dawkins *et al*. 2003; Hegelund *et al.* 2005; Jones *et al*. 2007; Hirt *et al*. 2000; Cooper and Hodges, 2010; Gilani *et al*. 2014; Gebhardt-Henrich *et al*. 2014).

Factors affecting range use in free-range laying hens

The use of range by laying hens have been studied and many factors have been reported to influence the ability of the hens to utilize the outdoor range (e.g. Bubier and Bradshaw, 1998; Carmichael *et al*. 1999; Nicol *et al*. 2003; Hegelund *et al.* 2005; Richards *et al*. 2011; 2012; Gilani *et al*. 2014; Gebhardt-Henrich *et al*. 2014). One of the major factors influencing the use of range is the design of the range itself (e.g.

the availability, distribution and type of resources in the range) with more hens reported to use the range when more enrichment resources are provided (e.g. Nicol *et al.* 2003; Hegelund *et al.* 2005). Resources such as trees, hedges, shades, forages, shelter belts and artificial cover/structures have been effectively utilized to attract more hens into the range (e.g. Nicol *et al.* 2003; Hegelund *et al.* 2005; Zeltner and Hirt, 2008a; Nagle and Glatz, 2012, Sherwin *et al*. 2013). This outcome suggested importance of enrichments in the range and that the provision of such resources in the range has the potential to maximize range use in free-range laying flocks. This further suggested that a barren environment is a limiting factor to the use of range and also a risk factor for feather pecking in free-range laying hens (Green *et al*. 2000). Providing cover for the hens in the range is thought to provide protection against predators and inclement weather conditions and result in reduced fearfulness in the birds (Collias, 1987). The reduced fearfulness may be as a result of the greater chances of protection they benefit from when they live in large groups as suggested by Newberry *et al*. (2001).

The effects of flock size, stocking density and house size on range use are not separable because the variation of one of the factors is likely to affect the effect of other factors on range use. A typical example is an increase in the number of hens in a shed of fixed size which will result in increased flock size as well as increased stocking density whereas keeping the same number of hens in a larger house would result in a decreased stocking density and same flock size, which can all influence range use. It has been reported that the total number of hens found in the range shared an inverse relationship with the house size, flock size and stocking density (indoors), with more hens reported to use the range when there were fewer hens in the flock and also at reduced stocking density (Bestman and Wagenaar, 2003; Hegelund *et al*. 2005; Gilani *et al*. 2014). The study carried out by Gilani *et al*. (2014) showed that the percentage of hens found in the range increased when the indoor stocking density decreased. They suggested that in smaller flocks, where hens were housed in smaller sheds, it may have been easier for the hens to access the range or that the hens kept in reduced stocking densities had reduced impediments and were able to move to the outdoor area. However, the outdoor stocking density appeared to have opposite (i.e. positive) effect on the use of range in laying hens. Sherwin *et al*. (2013) reported that there was an increased percentage of hens in the range when the outdoor stocking density was higher. The laying hens are social animals and this may explain why they have preferred to stay close to their flock mates in the range. Pettersson *et al*. (2016) suggested that the hens found in the range may have acted as enrichment to other hens in the shed or that the higher number of hens in the range had likely made the other hens (found in the shed) feel safer to use the range.

Climatic factors such as temperature, relative humidity, wind speed, wind direction, light intensity, atmospheric pressure, have been found to influence the use of range by laying hens (Nicol *et al*. 2003; Hegelund *et al*. 2005; Richards *et al*. 2011; 2012; Nagle and Glatz, 2012; Gilani *et al*. 2014). Hegelund *et al*. (2005) reported that the number of hens in the range was influenced by temperature, wind season and precipitation with evidence that more hens used the range with increased temperature (up to 17^{o}C before decreasing) but decreased when precipitation and wind speed increased. They also found that the hens range more during the autumn season, followed by summer, winter and spring respectively. Nicol *et al*.

(2003) studied 50 flocks case (feather pecking) flocks matched with 50 control (non-feather pecking) flocks and found that the use of range was greater in dull and calm conditions compared to when it was sunny, wet and cold in both case and control flocks. Richards *et al*. (2011) and (2012) investigated pop hole usage in laying hens and reported that temperature had a significant positive effect on the pop hole activities by the laying hens and likewise hours of sunshine. They also reported that there was a reduction in pop hole activities by the hens as the rainfall and wind speed increased. Although they only studied the pop hole activities of the hens using RFID technology, they suggested that it showed an indicator of movement by the hens and their intention to access the range. The study of Nagle and Glatz (2012) supported the existing evidence that temperature has a positive effect on range use, with reports that increases in the indoor and outdoor temperatures resulted in more hens using the shaded range area.

Laying hens have been reported to show daily variations in the use of range (Hegelund *et al*. 2005; Richards *et al.* 2011; 2012; Nagle and Glatz, 2012), although with mixed findings. Nagle and Glatz (2012) and Hegelund *et al*. (2005) found that range use by laying hens peaked in the morning but decreased in the afternoon whereas Richards *et al.* (2011) and (2012) reported reduced pop hole activities in the morning and greater activities in the afternoon. The difference between the outcomes of the above studies appeared to be related to the differences between the methods used. While Richards *et al.* (2011) and (2012) utilized RFID technology in studying the laying hen activities, Nagle and Glatz (2012) and Hegelund *et al*. (2005) carried out video observation and head counts respectively. Also, Richards *et al.* (2011) and (2012) studied only the pop hole activities of the hens and did not provide further evidence on whether the hens that used the pop holes actually continued into the range or not.

The influence of pop hole size and availability on the use of range by free range laying hens has been studied by Sherwin *et al*. (2013) and Gilani *et al*. (2014) and they found that the number of hens in the range increased when more pop holes were provided in the range. Evidence have shown that laying hens make use of pop holes frequently in the free-range was presented by Richards *et al*. Wall *et al*. (2004) suggested that the hens kept in furnished cages utilized the pop holes (connecting two cages) to achieve even distribution although they reported no evidence that the hens needed the pop holes to escape from aversive conditions e.g. feather pecking, aggression and cannibalism. The work of Wall *et al*. (2004) was carried out in a caged system but it provided good evidence that free-range laying hens can potentially use the pop holes to achieve a balanced distribution between the shed and the range. Increased availability of pop holes has been found to influence range use in laying hens with evidence that increased in the pop hole space available to the hens resulted in greater use of range in laying hens (Sherwin *et al*. 2013; Gilani *et al*. 2014). Richards *et al*. (2011) found that approximately 80% of laying hens used the pop holes at within two weeks of tagging and this may mean that the presence of large number of hens around the pop holes have the potential to limit the accessibility of the range by other hens. Providing more pop holes for the hens has potential to provide additional opportunities for more hens to access the range, provided that other limiting factors are minimized e.g. keel bone fractures (Richards *et al*. 2012).

The effect of age on the ability of the laying hens to use the range has been studied and mixed results reported (Hegelund *et al*. 2005; Richards *et al*. 2012; Gilani *et al*. 2014). Richards *et al*. (2012) and Hegelund *et al*. (2005) reported that the activities of the laying hens (pop hole and outdoor use respectively) decreased as their age increased whereas Gilani *et al*. (2014) found a decrease in range use with increase in the age of the hens. Richards *et al*. (2012) utilized a technological aid (RFID) in studying a group (1100 hens) of laying hens divided into four separate flocks and explored only the pop hole activity of the hens, without further information on whether the hens continued into the range or not. They suggested that the reduced pop hole activities may have been due to the poor physical condition of the hens at older age e.g. poorer plumage condition reported of the older hens (Tauson *et al*. (1984). Hegelund et al. (2005) studied 37 flocks of laying hens kept in free-range and organic systems, after housing them at approximately 16 weeks of age. They expected that the use of range in the studied flocks would increase with age, but instead found the opposite. They expected range use to increase as they hens got more familiar with the range environment, but other factors e.g. choice of behaviour (Channing *et al*. 2001) appeared to have more significant effect than the range familiarity. Channing et al. (2001) studied the distribution and behaviour of perchery housed laying hens at constant stocking density and found that older hens spent more time standing idle when compared to the younger birds. This also showed reduced activity level in the older hens when can further explain why the use of range decreased in older hens studied by Hegelund et al. (2005). However, Gilani *et al*. (2014) studied 33 flocks of young and adult laying hens and reported that range use increased as the hens got older during the laying period. The increased familiarity of the range area, associated with continuous daily exposure to the range appeared to have improved the ranging activity in the older hens which may have showed reduced fear responses and therefore more confident to leave their sheds (e.g. Grigor *et al*. 1995a).

Other important factors found to influence range use in laying hens include; rearing experience (e.g. Grigor *et al*. 1995a; Gilani *et al*. 2014), location of feed and water in the shed (e.g. Bubier and Bradshaw, 1998) and keel fractures (e.g. Nasr *et al*. 2012). The study of Grigor *et al*. (1995a) suggested that early exposure to range have the potential to influence the use of range in the later life of the hens. They found that hens with previous experience in the range emerged quicker from a test box and were also found to use the distant areas of the range compared to their counterparts with no prior outdoor experience (Grigor *et al*. 1995a). However, Gilani *et al*. (2014) did not find such effect on the range use of laying hens reared with range access during lay. They reported no difference in the percentage of range use between flocks that had access to the range during rearing and the ones that did not. They suggested that although outdoor experience may improve ranging (e.g. Rodriguez-Aurrekoetxea and Estevez, 2016) but they did not find any evidence that ranging experience at early age improved range use at later age. Bubier and Bradshaw (1998) observed that during their study, the hens returned to their shed close to feeding times (involving the running of feeder belts 4 – 6 times daily) to claim their places at the feeders and during this time, range use was found to drop. A reduction in pop hole activity was reported in laying hens with higher keel fractures (Richards *et al*. 2012). Their study indicated that laying hens with keel bone fractures were less likely to use the range as pop hole activity was described as an indicator or intention of the hens to use the range.

Enriching the range to improve outdoor turn out in commercial laying flocks

The enrichment working group of the American Zoo and Aquarium Association (BHAG, 1999) defined enrichment as a dynamic process that involve change of environmental structures and husbandry practices to increase the behavioural choices available to captive animals and help draw out their species appropriate behaviours and abilities. Also, Newberry (1995) defined enrichment as an improvement in the biological functioning of captive animals by modifying their environment. The definition of Newberry (1995) is in line with that of Shepherdson (1998), who described environmental enrichment as the husbandry practices that seek to enhance the quality of captive animal care through the identification and provision of environmental stimuli required for the optimal psychological and physiological stimuli. Broadly speaking, enrichment is a process and its emphasis is mainly on its dynamic nature rather than a definite state of an animal's environment. This further implies that enrichment requirements are likely to differ between animals, seasons, locations, sexes, ages and body sizes i.e. based on the needs of the animals.

Based on the definitions above, an environmental enrichment is can also be described as behavioural enrichment, as it seeks ways husbandry practices can be used to improve the living conditions of captive animals to meet their behavioural needs e.g. the provision of nest sites to encourage nesting behaviour in laying hens. A good enrichment programme should have the potential to add value to the immediate surroundings of the animals to enhance their physical, health, psychological and physiological well-being (Shepherdson, 1998) and when the optimal environment is provided, the specie specific range of normal behaviours should also be encouraged. The understanding of the specific behavioural, physiological and behavioural needs of an animal is an important tool in achieving their optimal enrichment and welfare requirement. Laying hens have been reported to place high value on nesting behaviour and also squeezed through narrow gaps to access discrete nest sites prior to egg laying (Cooper and Appleby, 1995; Bubier, 1996a; Cooper and Appleby, 2003; Smith *et al*. 1990). In this situation, enriching the hens' environment would include the provision of appropriate nest site for the hens to meet their behavioural needs and ensure good welfare. To understand the behavioural needs of laying hens, a comparison between the domestic and wild or feral chickens is important (Cooper and Albentosa, 2003), but it must be noted that domestic hens do not need to perform all behaviours seen in the wild or feral conditions (Dawkins, 2003) e.g. hens may not need to escape from predators when housed in cages. Lambrecht *et al.* (1999) argued that conclusions from studies carried out on captive animals can lead to wrong conclusions if they are carried out without the knowledge of the natural habitats where the animals evolved from. This implies that comparing the features of the environments where feral and captive animals live is valuable in determining the resource gap between them and also inform animal keepers on the likely environmental needs of the animals under their care. This argument in turn favours the provision of wild-like environment for the laying hens with the aim to provide the stimulations that are similar to the wild situations (Forthman-Quick, 1984; Ogden *et al.* 1993; Wormell and Brayshaw, 2000).

Resources like tree covers, foraging substrates, shelter belts grasses, hedges and tall weeds have been utilized in enrichment studies and the provision of these resources in the range encouraged more hens to leave the sheds to the range (e.g. Hegelund *et al*. 2005; Nagle and Glatz, 2012; Bosco *et al*. 2014; Gilani *et al*. 2014). Nagle and Glatz (2012) carried out a three-trial study that examined the role of shaded area, forages and shelter belts on the percentage of hens in the range and compared the effects of the three treatments (shaded area, forages and shelter belts) with a free-range that had no enrichments. They reported that there were 3 times more hens in the shaded area than the non-shaded area; 8 times more hens using the hay bale compared to the area without hay-bale and even 17 times more hens found in the shelterbelt than the non-shelterbelt area. They suggested that these three resources were all very successful on-the-farm resources to attract hens into the range and hence recommended their use to free-range egg farmers. Bosco *et al.* (2014) found that chickens kept in range environment used their range more compared to the control chickens (chickens without enrichments) that mainly stayed indoors. They studied the effect of range enrichment (using olive trees and stand of tall sorghum) on the ranging behaviour of free range chickens and reported increased outdoor use (more time spent in the range) and greater exploitation of the pasture. The study of Hegelund *et al*. (2005) reported similar effect of an enrichment resource on outdoor use. They provided artificial cover (dome shaped tents covered in camouflage nets) in the range and investigated its effect on the number and distribution of the hens in the range. They reported that there were significantly more hens in the range when the artificial cover was provided (11%) compared to when there was no cover (9%) and that more hens were attracted to the area further away from the range when the artificial cover was provided. Further evidence also showed that provision of enrichment resources in the range had similar attractive effects on the proportion of hens found in the range (Gilani *et al*. 2014) just like the other studies mentioned above (Nagle and Glatz, 2012; Bosco *et al.* 2014; Hegelund *et al*. 2005). They reported that more hens used the range and the also moved to the further areas of the range when cover (mature trees, hedges and high weeds) and artificial structures (farm buildings) were provided in outside. Range use has been negatively associated with fearfulness (Hartcher *et al*. 2015) and this suggests that the hens may have been less fearful in the range when cover was present (e.g. Nicol *et al*. 2009; Browne *et al*. 2010) or that the cover had offered them protection from bad weather to encourage range use (e.g. Grigor *et al*. 1995b). The possible explanation for the positive effect of foraging substrates on the use of range by laying hens could be that they peck on forages to derive nutritional benefits. Hens have indeed shown motivation to perform foraging behaviour even when access to feed is unlimited (Duncan and Hughes, 1972; Dawkins 1989).

Outdoor stocking density (number of hens/m^2) appeared to have an opposite effect on the ability of laying hens to use the range compared to the indoor stocking density. While indoor stocking density tended to limit range use (Bestman and Wagenaar, 2003; Gilani *et al*. 2014), outdoor stocking density was reported to have a positive influence on outdoor use, with more hens found outdoors when the outdoor stocking density increased (Sherwin *et al*. 2013). Pettersson *et al*. (2016)

suggested that the presence and proximity of the hens in the range may have served as enrichment to the ones in the shed by making them feel safer to use the range. Although there is scarcity of information in this area but the established evidence on the social facilitation or social transmission of behaviour in laying hens may explain the influence of the hens in the range on their non-ranging counterparts e.g. they may have copied the ones in the range (Nicol, 1989; Nicol, 1995; Nicol, 2006).

Previous (rearing) experience have been found to influence the use of range (e.g. Grigor *et al*. 1995a). They studied the effects of handling and exposure to an outside area on fearfulness and dispersal in domestic hens and found that the hens that had previous experience in the range emerged earlier from familiar box compared to the hens that had no prior outdoor experience. They suggested that regular exposure to the range during rearing is likely to increase their readiness to use the range at adult age. However, Gilani *et al*. (2014) found that range access during rearing had no effect on the use of range although they suggested that previous experience may improve ranging, but they did not find any evidence that the experience would be accrued at young age.

The factors affecting use of range in laying hens (e.g. indoor stocking density, climatic conditions, flock size, house size, house design, resources in the house) have been outlined earlier in this thesis and based on the evidence discussed, range use is influenced by many factors. It is rational to say that the provision of trees, forages, artificial structures, additional pop holes and rearing experience alone to the laying hens is likely to be insufficient to encourage them to use the range. It will be more beneficial to improve on the other factors (e.g. reduced indoor stocking density, reduced flock size and smaller house size) that affect range use alongside the outdoor enrichment strategies, for an optimum ranging pattern to be achieved.

Behaviours and their importance to the laying hens

Laying hens engage in different activities e.g. foraging, ground pecking, dust bathing, running, perching, flying, sitting, lying, wing flapping, wing stretching, walking, preening and standing, and there are potentially greater opportunities for them to perform the behaviours in the free-range conditions compared to the caged environments (Appleby and Hughes, 1991). The conventional cage husbandry system on the other hand has been criticized for imposing space and behavioural limitations on the hens, associated with poor welfare conditions (e.g. Dawkins and Hardie, 1989; Rodriguez-Aurrekoetxea and Estevez, 2016). Duncan (1998) described animal behaviour as 'a good indicator of the state of suffering e.g. fear, frustration and pain of the animal and allowing them to perform the behaviours the motivated behaviours is a key to good welfare (Olsson *et al*. 2002b). One of the Five Freedoms of animal welfare outlined by the UK's Farm Animal Welfare Council stated that captive animals should have freedom to express normal behaviours by providing sufficient space, substrates and company of their own type (FAWC, 1979). Normal behaviours are behaviours that are specific to an animal which is seen in the wild or feral animals (e.g. the behaviour repertoire of wild or feral chickens) and not in their domesticated or captive counterparts (e.g. Faure and Jones, 2004). Further to this, scientists have suggested that the genotype, environment and experience of the domesticated animals may differ significantly from their ancestors (Hughes and Duncan, 1988) and as such the domesticated animals may not need to perform all the behaviours seen in the wild or feral animals (Dawkins, 2003). Different behaviours have been studied and their importance to the laying hens have been measured using different approaches. These include;

(a) Comparing the behaviour of wild or feral chickens with that of the domesticated ones (e.g. Faure and Jones, 2004) to determine the behaviours that are not seen in the wild or feral conditions. This method is useful in exploring the behaviour range of hens but may fails to provide further details of the importance of behaviours to the hens (Cooper and Albentosa, 2003) and may even fail to account for behaviours that occur in different forms (Blokhuis and van der Haar, 1992). Dawkins (2003) argued that the modern domestic hens may not need to perform all the behaviours seen in their wild or feral counterparts. The typical example stated by Dawkins (2003) is that of caged hens, which may not need to escape from predators like their wild or feral counterparts do and judging the absence of this behaviour in caged hens may lead to misleading conclusion. The difference between the behaviours of the wild/feral and caged hens can be accounted for by the difference between their environments.

(b) Determining the behavioural needs, priorities and preferences of the hens (Cooper and Albentosa, 2003; Dawkins and Nicol, 2006). Behavioural need is referred to as the instinctive behaviours that are controlled by internal factors and performed by the hens even in the absence of the resources or optimum environmental conditions (Duncan, 1998). A typical example is the case of sham dust bathing seen in laying hens kept on wired floors with no litter substrates provided for them to fulfil the actual dust bathing behaviour (e.g. Hughes and Duncan, 1988). Behavioural priorities refer to situations where birds show motivation to work to gain access to resources or perform certain behaviour. Behavioural preference has been tested using consumer demand theory, involving the imposition of costs on resource use (Cooper and Albentosa, 2003). Behavioural priority study has been carried out on laying hens using resistance doors and the hens were found push doors with resistance of 3.5 – 10.0 N to access nest sites (Kruschwitz *et al.* 2008). The term behavioural preference implies the outcome of choice experiments e.g. the preference of domestic hens for different types of battery cage floor (Hughes and Black, 1973). It is important to note that the willingness or lack of it for the hens to work to access resources or behavioural opportunities can give an estimate of motivation but does not provide the evidence of any suffering in deprivation or the absence of such opportunities (Dawkins, 1988).

(c) Estimating the indicators of coping or suffering in animals e.g. fearfulness, feather pecking; increased locomotion, aggression and frustration in the hens (Meijsser and Hughes, 1989; Sherwin and Nicol, 1993; Zimmerman and Koene, 1998; Olsson and Keeling, 2000; Zimmerman *et al*. 2000). Laying hens have shown evidence of frustration when deprived of foraging opportunities (e.g. Blokhuis and Arkes, 1984; Blokhuis, 1986; Hughes and Duncan, 1988) and restlessness (Meijsser and Hughes, 1989) and pacing (Sherwin and Nicol, 1993; Yue and Duncan, 2003) in the absence of nest opportunities.

Feeding behaviour

Animals consume nutritive items and drink water to meet their nutritional needs and maintain their body weight. It has been suggested that laying hens place high value on food and this has been an important tool in measuring the value of other resources to the hens (Cooper and Albentosa, 2003) and have been used for testing the value or control of behaviours in animals (e.g. Duncan and Hughes, 1972; Olsson *et al*. 2002). Olsson *et al*. (2002) found that food deprived hens are motivated to open resistant doors to gain access to food. They reported that the amount of work (resistance) done by the hens increased significantly as the period of deprivation increased from 12 to 24 hours and also that the food deprived hens showed shorter latency to make contact with the weighted door compared to the non-deprived hens. Hens have shown a preference for feeding rather than other behaviours after a period of food deprivation (Cooper and Appleby, 2003; Petherick *et al.* 1993) and have also shown increased stereotypic behaviours e.g. pacing, pecking, aggression and calling, during food deprivation (Duncan, 1970; Duncan and Wood-Gush, 1971; Scott *et al.* 1999; Zimmerman and Koene, 1998). If laying hens have attached such high value to feeding, then it is reasonable to say that feeding is not just a need but also a preference and priority to the hens.

Foraging behaviour

Foraging behaviour has been described by Cooper and Albentosa (2003) as the pecking and scratching of potential food sources and the locomotory activities involved in searching and sampling of new sources of food. Hughes and Duncan (1988) have argued that the need to express foraging behaviour by laying hens may be removed if its ultimate goal (i.e. food) is provided, but this was not supported by other studies that reported persistence of foraging behaviour in domestic hens and red jungle fowls even with unrestricted access to feed (Duncan and Hughes, 1972; Dawkins 1989). Studies have suggested that hens may feather peck when adequate foraging opportunities are not provided (Blokhuis and van der Haar, 1992; Huber-Eicher and Wechsler, 1998). An example of this is a study where feather pecking was found to occur least frequently in a group of hens with good access to foraging substrates compared to the group that had no access to forage substrates (Huber-Eicher and Wechsler, 1998). Scientists have argued that laying hens deprived of foraging opportunities may be frustrated (e.g. Blokhuis and Arkes, 1984; Blokhuis, 1986; Hughes and Duncan, 1988). Blokhuis (1986) reported that there was increased feather pecking in the hens housed on wire-slatted floors compared to the ones kept in the house with litter floor, found engaged in greater ground pecking (foraging) activities. Further evidence in support of this claim is the study of Blokhuis and Arkes (1984) which found that hens that had no access to litter spent more time pecking on the feed trough and also on their flock mates compared to the litter-housed hens. Foraging behaviour has been described as a behavioural need for the laying hens based on the evidence that it did not decrease when cost was imposed on its searching and investigative phases (Bubier, 1996a; 1996b).

Dust bathing behaviour

Dust bathing is comfort behaviour and hens rely on it for body maintenance (Lindberg and Nicol, 1997; Van Liere and Bokma, 1987; Nicol 1989; Van Liere *et al*. 1990; Van Liere, 1992). European Food Safety Authority report (EFSA, 2005) further described dust-bathing in laying hens as a behavioural priority required to maintain good feather condition through the dispersion of lipids and elimination of parasites from the body. Hens have been reported to engage in bouts of sham or vacuum dust bathing (dust bathing in complete absence of substrates) on bare wire floors of battery cages and on bare floors (Hughes and Duncan, 1988; Baxter, 1994). Sham dust bathing has generated controversies with some scientists associating it to poor welfare (Vestergaard, 1982) and others arguing that it is a satisfactory alternative to the actual dust bathing behaviour (Van Liere, 1992) although the extent to which sham dust bathing can replace the actual dust bathing is not clear (Lindberg and Nicol, 1997). Scientists have found it difficult to determine the value of dust bathing to laying hens (Weeks and Nicol, 2006) and this view was shared by Cooper and Albentosa (2003) who also argued that the attempts to assess the value of dust bathing substrates by scientists have been faced with the difficulty in differentiating between the use of the substrates for foraging and the actual dust bathing. Laying hens appeared to place low value to dust bathing behaviour as research studies have shown that they did not place high priority it (Bubier, 1996b) or that they did not value it at all when access is allowed after a period of deprivation (Gunnarsson *et al.* 2000). Gunnarsson *et al.* (2000) reported that the hens have high demand for the litter substrates (straw and feathers) and used it for scratching and pecking, but not for dust bathing activities in the caged hens.

Nesting behaviour

Laying hens perform nest building activities (Hughes *et al*. 1989) and pre-laying behaviours e.g. locomotion and investigation, prior to oviposition (Duncan *et al*. 1978) and prefer to lay their eggs in secluded locations (nests) with evidence of strong need to use nest sites provided with straws or nest lining (Appleby and Smith, 1991; Ekstrand and Keeling, 1994; Smith *et al*. 1990; Wood-Gush and Murphy, 1970). Scientific evidence has shown that hens show high level of motivation to nest and have paid high costs e.g. squeezed through narrow gaps or open doors to access discrete nest sites prior to oviposition (Bubier, 1996a; Cooper and Appleby, 1995; Cooper and Appleby, 2003; Smith *et al*. 1990). Hens quickly learnt to slide through open doors to access nest sites (Smith *et al*. 1990). Cooper and Appleby (1995) reported that prior nesting experience of hens had no influence on their ability to seek nest sites. They found that the hens moved to nest sites from their home pens but did not move back to their home pens from nest sites prior egg laying. Hens have shown signs of frustration (e.g. gakel calls) in cages when nest site was not provided (Zimmerman *et al*. 2000) and there are further evidence of nest seeking activities in absence of nest sites in laying hens (Freire *et al*. 1996; Cooper and Appleby 1997). Laying hens show other signs e.g. restlessness (Meijsser and Hughes, 1989), pacing (Sherwin and Nicol, 1993; Yue and Duncan, 2003) and excessive feeding and preening activities (Duncan and Wood-Gush, 1972; Meijsser and Hughes, 1989) in the absence of nest sites. Nest seeking behaviours (Cooper and Appleby, 1995) and locomotor behaviours (Appleby *et al*. 1992; Meijsser and Hughes, 1989) were reduced when suitable nest sites were provided to hens.

Perching behaviour

Perching behaviour refers to the sitting, standing or lying of animals on objects above the ground. Laying hens use perches to reach resources, roost at night and avoid other birds (Duncan *et al*. 1992; Olsson and Keeling, 2000; Gunnarsson *et al*. 1999) and have been reported to use up to 100% of perches at nights when sufficient space is provided (Appleby *et al*. 1993; Olsson and Keeling, 2000). This showed that they attach high priority to perching activities at nights compared to daytime (Duncan *et al*. 1992; Bubier, 1996a). Hens without access to perches have been found to show signs of increased exploration, restlessness and increased movements especially towards dusk and have refused to access perches when in use by other hens (Olsson and Keeling, 2000). The above scientific studies have shown that laying hens placed high value on perches and it has been suggested that this important resource should be provided for the hens to perform this highly desired behaviour (Olsson and Keeling, 2000).

Chapter 3

Pilot study on the use of range by a small flock of laying hens

A pilot study was carried as a part of the preparation for the larger study and utilized a 72-week old flock, made up of 15 ex-caged laying hens at the Riseholme Park campus of the University of Lincoln, between June and July 2011. This study commenced immediately after the hens were allowed access into the range and mainly involved the preliminary methodological development stage and literature familiarization exercise. The main purpose of this study was to identify and refine the experimental protocols and collect data on a relatively small scale (flock of 15 previously caged hens maintained by University of Lincoln Animal Unit) usable in achieving the research aims and objectives stated earlier in this thesis. The study was conducted at the same time as the review of relevant methodological literature and identification of potential sites for the main experiment. Formal consultation with the director of studies and a potential commercial sponsor was also done alongside sourcing of experimental materials and making contacts with farmers for permission to access the project sites for familiarization and main farm visits. An initial visit of the project site was made, during which mapping of the outdoor area was carried out using measuring tape, lines, and 1-meter bamboo poles. The poles were used to make quadrats of 2m x 2m from the shed to the fence. Portable video cameras were set up and powered for audio visual observations. A direct observation was also carried out and data recorded on designated data sheets. These activities were repeated for subsequent visits. In addition to the video and direct observations, an effort was made to use a PLR laser range finder (Robert Bosch Holdings, Uxbridge, UK) to determine the nearest neighbour distances of the hens in the range, but was discontinued because of the difficulty associated with the spotting of laser light (red pointed light) during the day. The number of hens within each quadrat was counted and the position of each hen in relation to the shed (near the shed, mid-way between shed and fence and near the fence) was recorded during each sampling period. The behaviour and feather condition of one selected hen in each quadrat was recorded for 1 hour, from the outside of the chicken enclosure (just outside the fence) in line with the recommendations of Cooper and Hodges (2010). They recommended an observation distance of 10m from the hens as the disruptions to behaviour of the hens appeared to be minimal at this distance.

Results of the pilot study

The amount of data collected in this study was small and was mainly used for methodological familiarization purposes. The results showed that the hens preferred their sheds to the outdoor runs and the mean number of hens found outdoors at any one point was 1.00 ± 0.166 hens/quadrat. The hens that ventured out of the shed spent 2.15 ± 0.276 minutes in the paddock. The hens showed a skewed distribution in the range with significantly greater number of hens found near the shed ($F_{2,27} = 23.318$, $p < 0.0001$). The area nearest to the shed (within 4 meters) of the shed had 2.00 ± 0.149 hens/quadrat, followed by the 0.60 ± 0.221 hens/ quadrat in the mid-zone (4 – 8 metres) and the 0.40 ± 0.163 hens/quadrat found in the area near the fence (8 – 14 metres). Foraging was the most recorded behaviour outdoors (40.0 ± 9.097 %) followed by locomotion (33.33 ± 8.754 %), resting (16.66 ± 6.920 %) and comfort behaviour (10.00 ± 5.571%) respectively and no aggression was recorded during the study. The proportion of foraging ($F_{2,27}$ = 0.1.688, p = 0.204), locomotion ($F_{2,27}$ = 1.016, p = 0.375), resting ($F_{2,27}$ = 0.220, p = 0.804) and comfort ($F_{2,27}$ = 0.100, p = 1.00) behaviours recorded outdoors did not differ significantly between the three areas (Table 3.5).

	Outdoor areas			
Behaviour	Near shed	Mid-way	Near fence	SEM
Foraging (%)	20.00	60.00	40.00	9.097
Locomotion (%)	50.00	20.00	30.00	8.754
Resting (%)	20.00	10.00	20.00	6.920
Comfort (%)	10.00	10.00	10.00	5.571

Table 3.0 showing the behaviour of hens in the range. There were more movements near the shed and greater foraging activities in the middle area but comfort behaviour remained similar in all areas. The differences in the proportion of foraging, locomotion and resting behaviours between the three areas were not statistically significant.

The result of the pilot study suggested that the prior experience of the hens in the cages had a negative effect on their ability to use the range as they spent most of their time in the shed. The hens were re-homed at 72 weeks of age (i.e. after spending their productive life in the cage) and they appeared to have been accustomed to the smaller space, usually associated with reduced movements and greater standing and resting behaviours (Rhim, 2014). The experience of the hens in the cage appeared to have influenced their ability to use the range e.g. previous experience have been reported to affect space use in domestic hens (e.g. Grigor *et al*. 1995a) and with space use found to be negatively associated with fearfulness

(Hartcher *et al*. 2015), it was possible that the non-exposure of the hens to the outdoor area during rearing period had resulted in fearful responses leading to poor outdoor use.

The outcome of this pilot study showed that the developed data collection protocols are useful and may be replicated in larger studies of range use in free-range laying hens and based on this, it was used in a larger study presented in chapter 4 of this thesis.

Chapter 4

Survey of the use of range in six flocks of commercial free-range laying hens

This chapter contains a cross-sectional study carried out on six flocks of commercial free-range laying hens. The study explored the use of outdoor area, nearest neighbour distance (NND), behaviour and feather condition of the laying hens and published under the title 'Ranging Behaviour of Commercial Free-Range Laying Hens (Chielo *et al*. 2016) alongside the completion of this thesis (See Appendix). The aim of the study was to explore the distribution of hens in the range (e.g. number of hens per quadrat in the apron, enriched and outer range zones) and to also determine if there were differences in the behaviour, NND, and feather condition of the hens found in different outdoor zones. The experimental protocols, results and discussions of the findings in relation to other published studies are also presented below.

Research hypothesis

In this study, different factors affecting ranging behaviour were considered and the null hypotheses (H_0) stated that the distribution, behaviour, NND and feather score of the hens will be similar in all the outdoor zones and time of the day, age, flock size, strain, temperature, RH and location of pop hole on either one or two sides of the range will not have any effect on outdoor use.

Alternative hypothesis (H_1) on the other hand would mean that the number, behaviour, NND and feather condition of the hens in the range would be affected by outdoor zone and time of the day, age, flock size, strain, temperature, RH and pop hole location.

Materials and methods of the six-flock study

Animal population and management

The study population consisted of medium hybrid lines commonly used in egg production: 3 flocks of Hyline and 3 flocks of Lohmann Brown hens (Table 4.0). The flock size ranged from 3,900 to 23,548 hens (Mean = 13, 598 ± 2857) and aged between 27 and 55 weeks of age (Mean = 47.0 ± 4.123). The study was carried out between November 2011 and February 2012. Each flock was visited 4 times for data collection, making a total of 24 days of data gathering and visits were arranged in advance with farm managers (at least one week prior to the date of data collection) and visits usually lasted from 8.30am to 4pm. Flock data such as age, strain, initial stock/population size and mortality were also recorded for each flock to enable the classification and analysis of flock variables. Boots, bamboo poles and hand gloves were usually dipped in disinfectants during and after visits and a 48hour gap was allowed between farm visits to comply with Noble Foods bio security requirements.

The hens were housed and managed according to the Council Directive (1999/74/EC), with free daytime access to the outdoor runs through ramped pop holes located on the sides of the sheds. The sheds comprised scratch area, litter, nest boxes, drinkers and feeders and offered the hens *ad libitum* access to feed and water. The hens were offered greater opportunities to engage in extensive locomotion within the outdoor enclosures with daily exposure to sunlight. Continuous lighting was provided in the sheds for a minimum of eight hours each day and the hens had daytime access to the outdoor range at 20 weeks of age through the pop holes measuring 45cm (H) x 2m (W) on either one or the both sides of the sheds. There was at least 2m pop hole opening per 1000 hens with the flaps usually opened at 9am every morning and closed at dusk (between 4 and 6pm daily) during the study period. In addition to complying with the requirements of the EU Council Directive, the hens in all the flocks had access to additional resources known as activity kits (Figure 4.0) in the range comprising of one set of mini shelter, dust bath and a perch per 4000 hens in the outdoor area. Trees were planted between the distance of 10m and 50m from the sheds, with most the activity kits located at the distance of 15 - 35m from the shed. The activity kits served as enrichment resources for the hens by increasing the complexity of the range environment.

Flock Code	Strain	Flock size	Mortality (%)	Age (weeks)	Location of pop hole (sides of the shed)
Cul8k	Hyline	7,300	8.75	48	2
Cul16k	Hyline	15,573	2.67	27	2
Kym4k	Hyline	3,900	2.5	55	2
Wds16k	Lohmann brown	15,470	3.31	49	1
Wil16k	Lohmann brown	15,797	1.27	51	2
Wil24k*	Lohmann brown	23,548	1.88	52	1

Table 4.0 Flocks and their characteristics including strain, number of hens at time of study and age in weeks at the time of study. The flock codes are assigned to represent flock, farm, and the flock size in thousands (k) *Single shed housing two flocks of approximately 12,000 birds each.

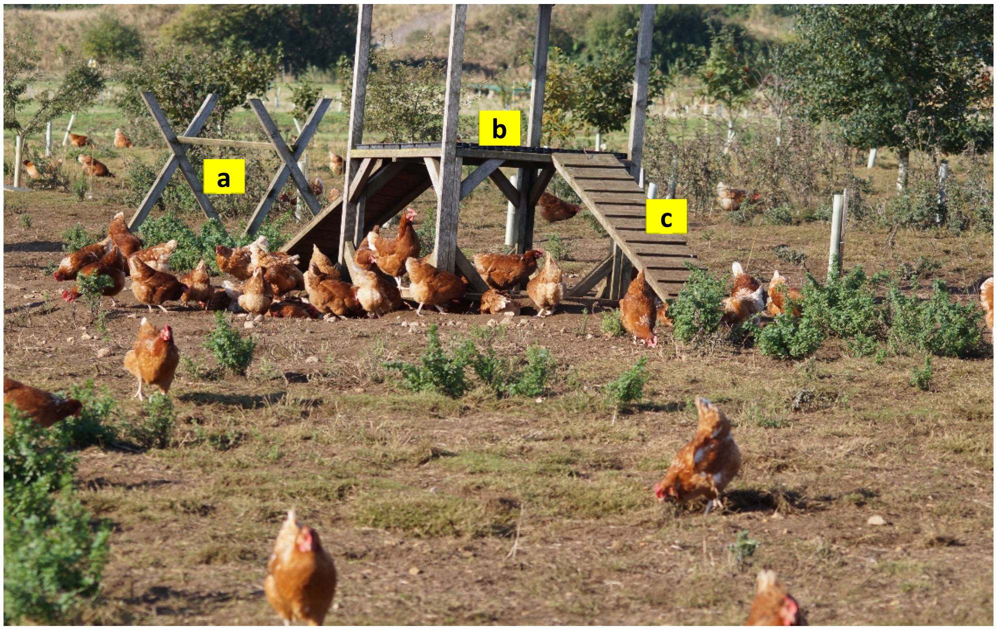


Figure 4.0 Showing activity kits (a) perch and (b) mini shed and (c) climbing frame.

Sampling area and tools

Each of the six free-range laying flocks used in this study was visited within 1 or 2-week period, in a cross-sectional study. During the initial visits, each flock was walked and key environmental features including location of shed within the field, field boundaries, location of pop-holes and the distribution of outdoor resources noted. The outdoor area had features (different enrichment resources) that were used to differentiate three discrete zones occupying specific locations in the range. Three discrete zones whose features were common across all the six flocks were identified in this study and these were the apron, enriched and outer range zones. The apron zone was defined as the area between 0 - 10m from the shed where no enrichment resources or tree cover was provided (Figure 4.2). The ground vegetation was sparse, with soil, slats, concrete or pebbles covering most of the area. This zone constituted 4.1% of the available outdoor area. The enriched belt covered the area between 10 - 50m from the shed and enrichments known as activity kits were found in this area (Figure 4.3). Ground vegetation varied from low grass pasture, with patches of taller perennial plants such as nettle and patches of bare earth, particularly where the hens had formed scrapes or dust baths. This zone constituted on the average 21.2% of the available outdoor area. The outer range was located from 50m and beyond i.e. from the end of the enriched belt to the end of the field (Figure 4.4) and it is the largest part of the outdoor area covering 74.7% of the available outdoor range. This area consisted mainly of grass pasture and low sward during the study period. The boundary for all flocks was made up of 2m tall electrified wire fence meant to control movement of the hens and also prevent ground predators from accessing the enclosure.

A 50-metre measuring tape was used in this study to measure the quadrats from the sides of the sheds covering the three outdoor zones and also the nearest neighbour distance of the hens. The bamboo poles were erected to mark each 10-metre point running perpendicular from the sides of the sheds to the end of the range and this, used in combination with the lines was meant to ensure that straight lines were maintained. These lines represented different transects and each transect was made up of 11 quadrats. A total of 4 transects were set out at right-angles from the two sides of the shed through to the end of the range (Figure 4.1) and this comprised of sequence of 10m x 10m quadrats. This quadrat size was utilized by Cooper and Hodges (2010) and was adapted for this study as it had a good chance of containing representative number of hens in the range. The use of smaller and larger quadrats was considered, but was thought to have a number of limitations e.g. smaller quadrats (e.g. 1m x 1m) are likely to give many counts with no chickens especially in the outer range. On the other hand, larger quadrats e.g. 15m x 15m quadrats would not fit into the apron zone and are likely to contain larger number of hens, whose estimation is likely to take more time. In flocks where pop holes were located on one side of the shed, the 4 transects were set out on one side of the shed. Bamboo poles were used to mark the quadrats and also produce the sighting lines used in walking the flocks. The hens were habituated to the pole for 30 minutes in line with the recommendations made by Cooper and Hodges (2010). They suggested that the poles provided short term point of interest to the hens when initially placed in the ground, but the hens quickly habituated to their presence and the poles did not influence the hens' location and behaviour after half an hour.

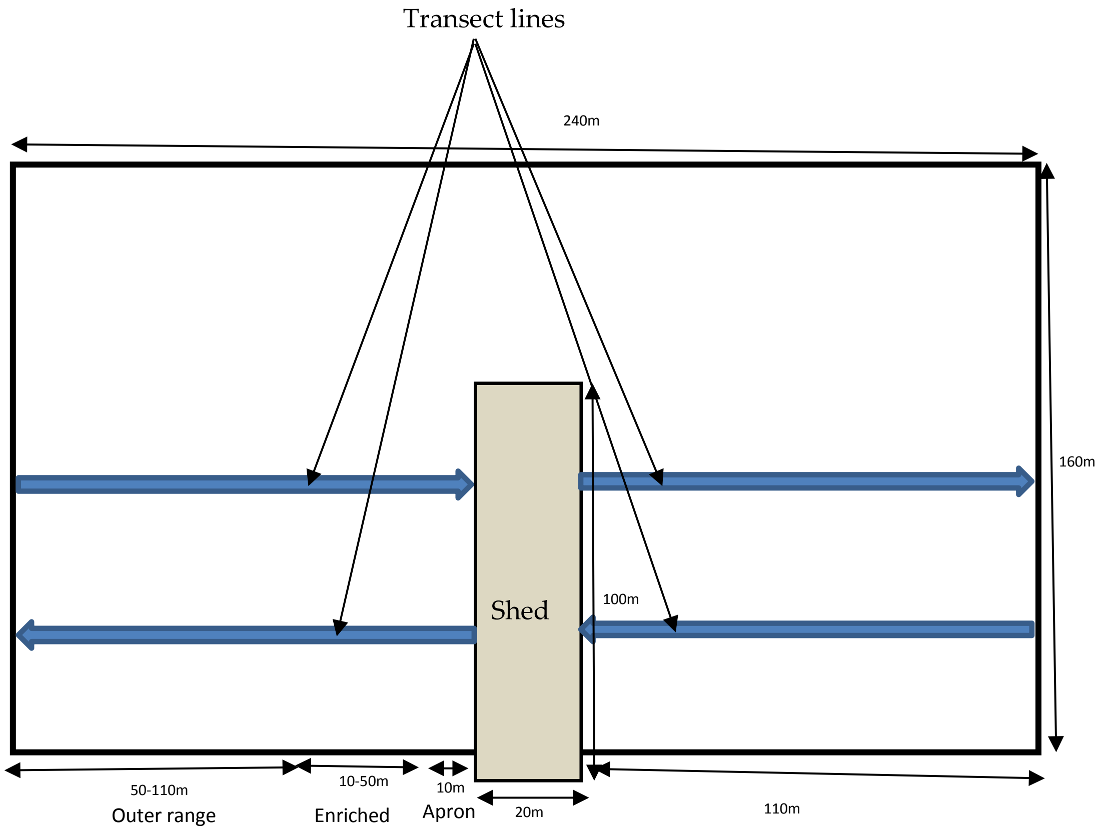


Figure 4.1 A typical outdoor range for 8, 000 laying flock, with pop holes on two sides of the shed. The 4 transect lines (containing 11equal sized quadrats each) run from the sides of the shed to the outer range. Data collection was carried out in the direction of the arrows.

Figure 4.2 Apron zone consisting of no enrichment resources, sparse ground vegetation, loose soil and pebbles.

Figure 4.3 The enriched region of the range containing enrichments such as grasses, mini shed, perches and plants.

Figure 4.4 Showing the outer range area (the most distant part of the range) made up of grass pasture.

Data collection protocols

Estimate of the proportion of the laying hens in the range

A general outdoor head count was carried out twice per visit (between 12pm and 1pm) for each flock to determine the proportion of the whole flock using the outdoor runs. This count was carried out separately and involved walking of the entire range of each flock twice and counting all the hens in sight covered (including the hens outside the quadrats). During each sampling period, the number of hens were counted on both sides of the transect lines and the numbers recorded according to the location of the hens e.g. apron through to end of the outer range. The numbers were totalled and used to estimate the proportions of the entire flock that were found outdoors and the proportion of the hens in different zones.

Estimate of the number of hens in the quadrats

Hen distribution was estimated using the marked quadrats, transect lines and by carrying out direct head count of the hens in all the quadrats. The head counts were carried out at different times of the day (10am, 11am, 1pm and 2pm for each visit) and the data used to determine the effect of time of the day on the ability of the hens to use the outdoor runs. During the quadrat head counts, only the hens found within the marked quadrats were counted with the observer-hen distance of 10m maintained to minimise potential observer influence on the hens. Hen distribution and habitat use patterns were derived using the head count data from all the observations across all visits.

Behaviour observations in the range

For this study, direct observations were carried out in the range during which a selection of hens in all the three outdoor zones (including hens within and outside the quadrats) was observed between 2 – 3pm of each farm visit. A focal and instantaneous sampling technique (Martin and Bateson, 2007) was used throughout the study and in 2 sampling bouts, the hen closest to the observer (reference hen) was selected and its behaviour recorded. The behaviour of every second hen to the reference hen was recorded until a total of 20 hens was achieved in each of the outdoor zone (giving a total of 120 behaviour samples per visit). An ethogram of behaviours (Table 4.1) was used to identify the 16 mutually exclusive behaviours of 20 chickens from each outdoor zone twice during each visit. Where there were fewer hens in a quadrat e.g. in the outer range zone, the behaviour of all the hens found in the quadrat was recorded.

Category	Activity	Description
Resting	Standing	Not moving on two feet, body not touching the floor
	Sitting	Body and both hocks touching the floor underneath or directly on either side of the bird
	Lying	Lying on its side, with both feet on the same side of the bird
	Perching	Sitting, standing or lying on poles or objects above the ground
Locomotion	Walking	Slow locomotion, the first foot is put down on the floor before the second one is lifted (without pecking or scratching)
	Running	Rapid locomotion, the second foot is lifted before the first is set down
	Flying	Active movement through air with wings
Foraging	Ground/object pecking	Pecking on the ground or objects
	Foraging	Walking while pecking on grasses and plants
	Ground scratching	Stepping backwards whilst raking the feet across the floor
Aggression	Aggression	Fights including pecking at another chicken, including aggresive displays, threats and chases
Comfort behaviour	Dust bathing	Foot scratching and bill-raking the litter or lose soil, followed by vertical wing shaking, head rubbing, bill-raking and /or scratching with one leg whilst lying
	Stretching	Elongation of the leg not associated with walking
	Wing flap	Includes wing flapping, body shaking, feather ruffling and tail wagging but not preening
	Preening	Moving the beak over the feathers
	Shaking	Rapid whole body movement mostly associated with ruffling of the feathers or shaking dust from the plumage

Table 4.1 Ethogram of the behaviours observed (Adapted from Buijs, 2011).

Assessment and scoring of the feathers

A direct visual assessment of the plumage condition of 4 body parts (head, neck, chest and back) of 120 hens was carried out and numerical values assigned to each body part according to the degree of feather cover or loss on a 6-point scale (Bilcik and Keeling, 1999). Values from 0 (best feathers) to 5 (worst feathers) were assigned to the assessed body parts (See table 4.2 for scale values and descriptions). Other feather scoring systems used in scientific studies include 5-point, 4-point and 3-point scoring scales which involve giving single scores to either the whole body (Hughes and Duncan, 1972) or different body parts of the hens (Allen and Perry, 1975; Tauson *et al*. 1984; Gunnarsson *et al*. 1995; Bilcik and Keeling, 1999; Tauson *et al*. 2005). Feather scoring was carried out immediately after behavioural observations and on the same hens whose behaviours were recorded. A total of 20 hens were feather scored in each zone in two sampling periods to give a sum of 120 hens during each farm visit. The feather data was recorded based on the location of the hens in range (apron, enriched and range) for the purpose of analysis. For the purpose of standardization, a similar protocol used for the behaviour observations above was followed i.e. a reference hen (the hen closest to the observer) was selected and its feather condition scored, followed by the feather scoring of every second hen to the reference until 20 samples was achieved in each zone.

Score	Body feathers	Flight feathers
0	Intact feathers	Intact feathers
1	Some feathers scruffy up to 3 missing feathers	Few feathers separated but not broken or missing.
2	More damaged feathers, greater than 3 feathers missing	A lot of feathers separated and/or a few broken or missing
3	Bald patch < 5 cm diameter or < 50% of area.	All feather separated, a lot of broken or missing feathers
4	Bald patch > 5 cm diameter or greater than 50% of area	Most of feathers missing or broken
5	Completely denuded area.	Almost all feathers missing

Table 4.2 Description of feather scoring method used to evaluate feather condition of the hens (adapted from Bilcik and Keeling, 1999).

Measurement of the nearest neighbour distance (NND)

Nearest neighbour distance is the estimate of how close or far away a hen is to the nearest individual in the flock. The NND of 20 selected hens was measured using measuring tape and bamboo poles. The measurements were carried out in all the outdoor zones and it consisted of selection of the hen nearest to the observer (reference hen) and its distance from the nearest individual measured. After the NND of the reference hen was carried out, every second hen to the reference hen was selected in each zone and their distance to the nearest neighbours measured and recorded. NND was carried out twice during each farm visit. The approximate location of the reference hens and their nearest neighbours was noted with the help of a field assistant and the NND determined by running a portable measuring (25 m) tape between two 1 m bamboo poles used in marking their locations.

Temperature and relative humidity (RH) measurements

The temperature and relative humidity of the flock sites were measured using a simple indoor/outdoor digital LCD thermo-hygrometer. The outdoor temperature and relative humidity was recorded every hour and from the start time to end of each farm visit. The recorded data represented the temperature and RH of all the outdoor zones and to ensure that this standard was met, the thermo-hygrometer device was positioned mid-way between the shed and the end of the range before the start of data collection for each farm visit. The data was recorded in printed data sheets and later transferred to a spread sheet at the end of each visit.

Statistical analysis

All the data collected for this study was analysed using SPSS 20.0 statistical software (IBM Corporation, Armonk, NY, USA). A general linear model analysis of variance (GLM ANOVA) was carried out on all the data to determine if the potential predictors of the use of range and their interactions had significant influences on the distribution of hens in the range. The study population comprised of laying hens from different farms and flocks and also hens of different ages, strains and flock sizes (which constituted the predicting factors of range use), were fitted into the model used in the analysis. The outdoor zone, time of the day, strain and position of pop holes were treated as fixed factors; farm and flock origin as random factors and age, strain, flock size, temperature and RH were fitted as covariates. A model simplification process was carried out and in this process, non-significant main effects and interactions ($p>0.05$) were removed from the model on a step-wise basis to achieve a fitted model (a model with only significant variables).

The NND data were analysed using a separate GLM developed in a similar way as the distribution model above to determine if the location, age, strain of the hens in the range influenced their distances from the nearest neighbours. In this model, outdoor zone, strain and position of the pop holes were fitted as fixed factors; flock and farm origins were treated as random factors and age, flock size temperature and RH were fitted as covariates.

Feather scores obtained from four body parts (head, neck, chest and back) of the hens were explored for descriptive statistics and also analysed using a GLM analysis to determine if the feather condition of the hens differed significantly between the outdoor zones. Outdoor zone, strain and position of the pop holes were fitted as fixed factors; flock and farm origins were treated as random factors and age, flock size temperature and RH were also fitted as covariates in this model. A fitted feather score model was achieved using the same approach as in the NND model above.

A data reduction process was attempted on the behaviour data using principal component analysis (PCA). The PCA procedure was discontinued as there was fewer than two cases i.e. only one variable was computed. Alternatively, the 16 mutually exclusive behaviours were grouped into 5 distinct behaviour categories before further analysis was carried out. The behavioural data were explored with descriptive statistics to determine the proportion of each of the behaviours recorded in the range. A separate model was developed for each of the behaviour categories to determine if the predictor variables had significant effects on the proportion of the behaviours recorded in the range. The predictor variables e.g. outdoor zone, strain and position of the pop holes were treated as fixed factors; flock and farm origins were treated as random factors whereas the age, flock size temperature and RH were fitted as covariates in the model.

A simple Pearson's product-moment correlation analysis was carried out on the distribution and NND datasets to establish if there was a relationship between the number of hens and their NND in the range. The analysis was carried out in four phases to reflect the overall, apron, enriched and outer range relationships. The general range use data was correlated against its NND counterpart and likewise data from the apron, enriched and outer range usage were correlated against their NND counterparts. This was to determine the overall relationship between range use and NND of the hens as well as the relationship between the hen number and NND of the apron, enriched and outer range areas.

The means and standard errors of means for the estimates of distribution, feather condition, NND, behavioural occurrence, temperature and relative humidity are presented in the result section of this chapter. The residuals of all the fitted models were tested for normality using a graphical (histogram) procedure and was found to be normally distributed, indicating that data transformation was not required for all analysis (See Appendix). Where further *post hoc* tests were carried out to determine the pairs that were significantly different from each other, a Bonferroni correction was applied to avoid the rejection of the null hypotheses.

Summary of results

The results showed that temperature and relative humidity varied across the study period, in line with seasonal variations and influenced the use of range. The results of the estimate of outdoor use indicated that 12.5% of the hens were found in the range at any one time and that greater proportion of the hens in the range were found in the apron zone and decreased with increasing distance from the shed. The result of the quadrat data analysis also showed a similar pattern on outdoor use by the hens i.e. there were more hens/quadrat in the apron than in the enriched and outer range zones and likewise more hens in the enriched zone compared to the outer range area. There was evidence that the hens used the range most in the early morning followed by a progressive decrease in the number of hens/quadrat through the day. The NND was greatest in the outer range and decreased towards the shed area. The results of feather score analysis showed the hens found in the outer range had the best overall feather condition and that neck feathers had the greatest scores (worst feather) whereas the side feathers had the least feather score (best feather condition). The hens that used the range engaged most in foraging behaviour, followed by resting, locomotory, comfort and aggressive behaviours respectively. There was evidence that the proportion of resting, foraging and locomotory behaviours were significantly influenced by the location of the hens in the range, with greater resting recorded in the apron zone whereas the outer range zone was dominated by foraging and locomotory activities. The findings of the current study supported that of previous studies which reported fewer hens in the range and greater use of areas closer to the shed in free-range laying flocks.

Effects of outdoor temperature and RH on the use of range

The average local temperature recorded during the study was 8.56 ± 0.06 °C (ranging from 0.70 °C to 17.5 °C), and the relative humidity was 72.6 ± 0.23% (ranging from 42.0% to 99.0%). The temperature and relatively humidity varied across the study period, following the seasonal changes in the climate and consequently there was significant variation in both temperature ($F_{5,4218} = 232.646$, $p < 0.001$) and relative humidity ($F_{5,4218} = 161.806$, $p < 0.001$) between farm visits. Temperature ($F_{1,4194} = 16.88$, $r = 0.148$, $p < 0.05$) and RH ($F_{1,4194} = 6.54$, $r = 0.007$, $p < 0.05$) had significant effects on the number of hens found in the range. The hens use of the outdoor range increased significantly as the temperature and RH increased.

Proportion of the hens and their distribution in the range

The percentage of the hens found outdoors was calculated separately for each flock and then averaged to achieve the overall proportion of hens in the range. The results of the general estimate of outdoor use showed that the mean number of hens out of shed was 1142 ± 91 (hens) which represented an average 12.5% of the flocks. An average of 530 ± 37 hens used the apron area (5.4% of the flock), whereas 401 ± 51 hens was found in the enriched belt (4.3% of the flock), and 211 ± 44 hens (2.8% of the flock) in the outer range area. This result suggested that most of the hens that used the range were found in the apron, followed by the enriched and outer range areas respectively.

Measure of quadrat use by the hens

The only factor excluded in the fitted distribution model was pop hole; thus leaving the zone, strain, time, flock size, age, temperature and RH (See Appendix) as the only significant factors on range use. Based on this, this result section will consist of the significant factors included in the fitted range use model. The number of hens in the marked quadrats was found to differ between the three outdoor zones with zone found to have a significant effect on the number of hens the quadrats ($F_{2,4198} = 65.270$, $p < 0.05$). Apron zone was made up of the first quadrat only and had 30.87 ± 0.44 hens/quadrat; Enriched zone was made up of quadrats 2 to 5 and had 8.97 ± 0.22 hens/quadrat; whereas outer range zone consisted of quadrats 6–11 with 1.60 ± 0.18 hens/quadrat (Figure 4.5). These counts amounted to about 3.24 m^2 per hen in the apron area, 11.1 m^2 per hen in the enriched belt and 62.6 m^2 per hen in the outer range quadrats and that translated to the population densities of 0.31 hens/m^2 in the apron, 0.09 hens/m^2 in the enriched and 0.02 hens/m^2 in the outer range zones. This evidence showed that apron was the most densely populated zone and that the hens in this zone had the least usable space, compared to the enriched and outer range users. Range use was found to generally decrease with increased distance from the shed, regardless of the age and strain of the hens and likewise the flock size, time of the day and location of the pop holes on the sides of the sheds. There were greater variations (SEM) in the number of hens found in the quadrats closer to the shed but these variations decreased as the distance from the shed increased. The apron zone was the part of the range closest to the shed and was found to have the greatest number of hens/quadrat compared to the enriched and outer range areas. Outer range had the least number of hens at any given time during the study.

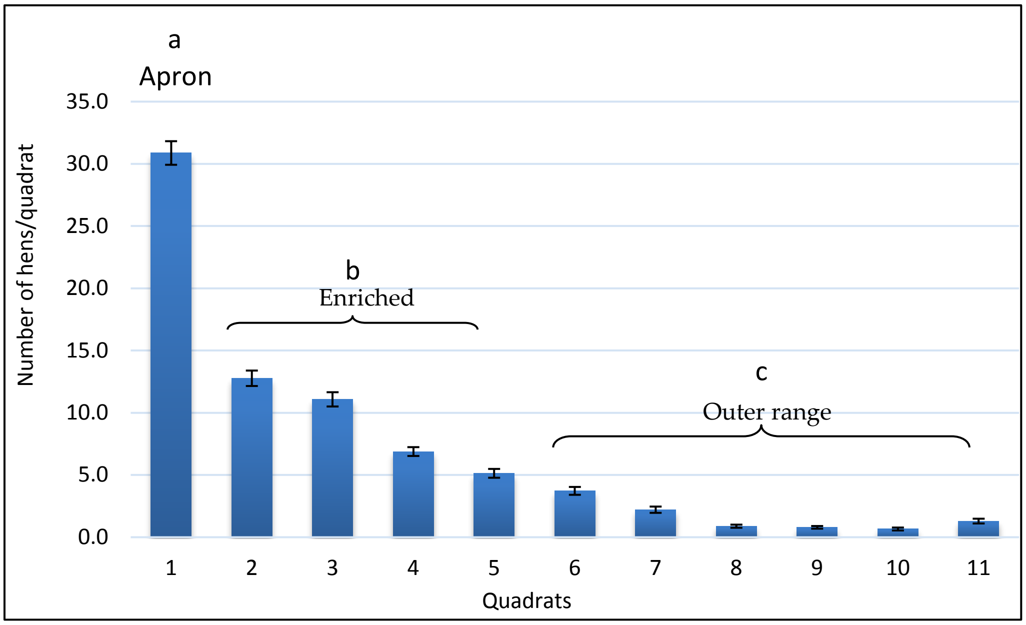


Figure 4.5 Showing that the number of hens/quadrat in the range decreased with increasing distance from the shed. [a,b,c] Means that zones with different superscripts are significantly different ($p < 0.05$).

Effect of time of the day on the use of range

Time of the day had a significant effect on the use of different areas of the range with localized effect of time on the use of range detected by the interaction between time of the day and zone ($F_{6,4198} = 32.08$, $p < 0.001$). This indicated that the number of hens within the three outdoor zones varied through the day. Further *post hoc* tests showed that there was a significant difference in the mean number of hens/quadrat recorded between the time periods in the apron ($F_{3,380} = 17.39$, $p <$ 0.001) and outer range zones ($F_{3,2300} = 6.17$, $p < = 0.001$) but not in the enriched belt ($F_{3,1532} = 2.55$, $p = 0.054$). The number of hens recorded between the three outdoor zones also differed significantly at all times i.e. 10a.m ($F_{2,1053} = 834.760$, $p < 0.001$), 11a.m. ($F_{2,1053} = 460.667$, $p < 0.001$), 1p.m. ($F_{2,1053} = 340.770$, $p < 0.001$) and 2p.m. ($F_{2,1053} = 402.673$, $p < 0.001$), suggesting that range use varied between the outdoor zones at all the time periods. The result of the interactions meant that there were more hens in the zones closer to the shed than in the farther range locations at all times i.e. the apron zone had more hens/quadrat than the enriched and outer range zones and that the enriched belt had more hens/quadrat than the outer range zone at all times and likewise there were more hens outdoors in the earlier hours e.g. 10 a.m. compared to the later hours e.g. 1 p.m., in the apron and outer range zones but not in the enriched area (Figure 4.6).

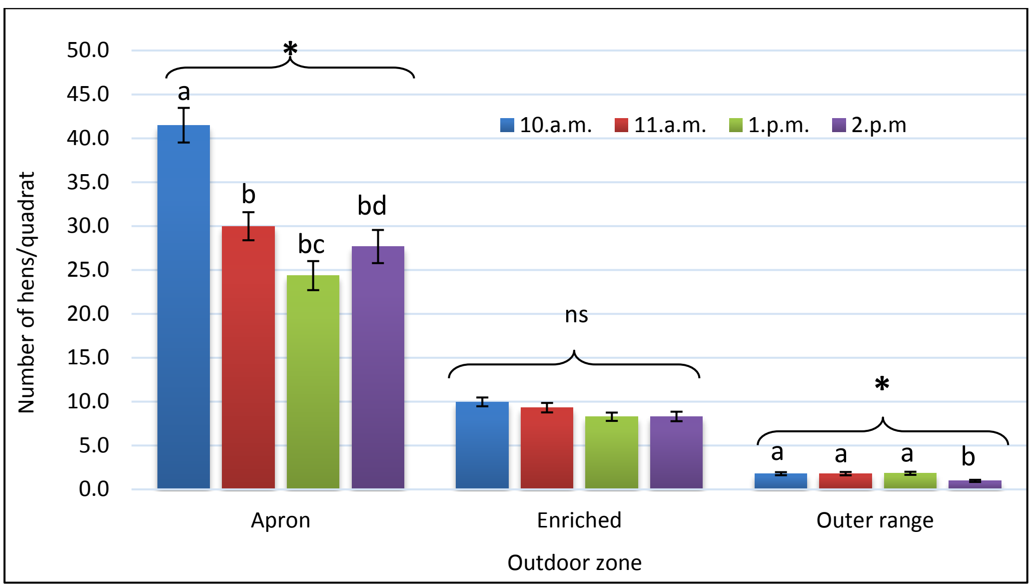


Figure 4.6 Showing the mean (±SEM) number of hens/quadrat at 10a.m., 11a.m., 1p.m. and 2p.m. differed significantly between the apron, enriched and outer range zones. * Means that difference between times in a zone is significantly different ($p < 0.001$), [ns] Means that difference between times in a zone is not significantly different ($p > 0.05$).

Effect of strain on the use of range

The results showed that the strain of the laying hens had a significant effect on the use of different outdoor zones. Outdoor zone interacted with strain ($F_{1,4198} = 13.73$, $p < 0.001$), which indicated that the use of the three outdoor zones varied between the strains of the hens (Figure 4.7). There was a significant difference between the use of apron, enriched and outer range zones by the Hyline ($F_{2,2109} = 887.307$, $p < 0.001$) and Lohmann Brown ($F_{2,2109} = 1051.159$, $p < 0.001$) hens, with both strain of hens found to use the apron zone most compared to enriched and outer range areas and the enriched zone was used more than the outer range zone. There was a significant difference between the mean number of the Hyline and Lohmann Brown hens recorded in the enriched ($F_{1,1534} = 42.05$, $p < 0.05$) and outer range zones ($F_{1,2302} = 13.07$, $p < 0.05$) but not in the apron area ($F_{1,382} = 0.04$, $p = 0.837$). This suggested that Hyline and Lohmann Brown hens showed similar use of apron area but there was more Hyline hens in the enriched and outer range zones compared to their Lohmann Brown counterparts. This further suggested that the variation in outdoor use between the two strains occurred in the enriched and outer range zones but not in the apron zone.

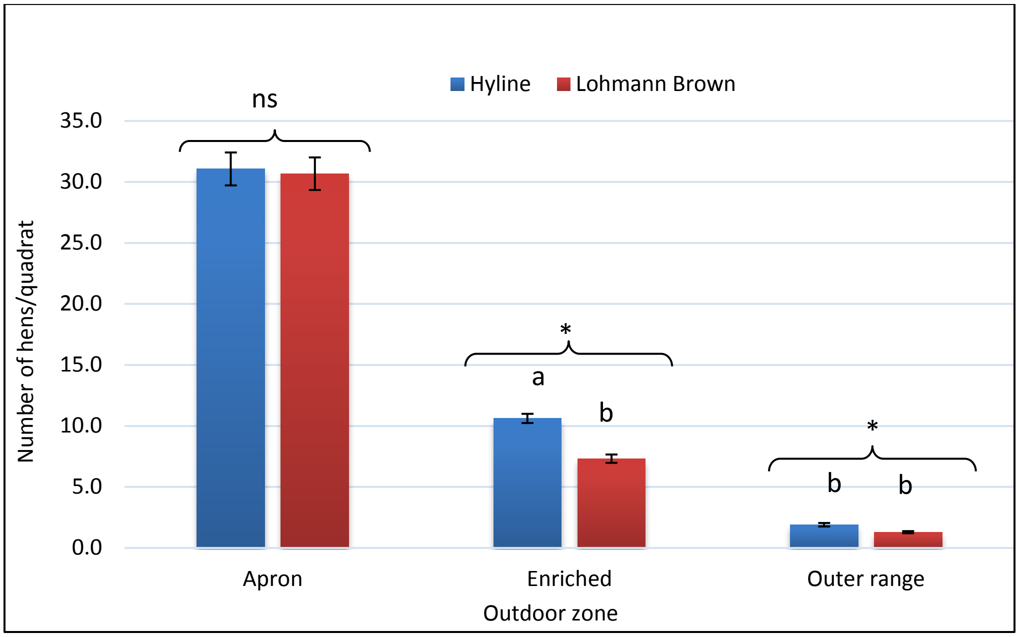


Figure 4.7 The use of different outdoor zones (hen/quadrat) by the Hyline and Lohmann Brown hens. * Means that difference between strains in a zone is significantly different ($p < 0.001$), ^{ns} Means that difference between strains in a zone is not significantly different ($p > 0.05$).

Effect of hen age on the use of range

The results showed that age of the hens had a significant effect ($F_{1,4198} = 15.08$, $p < 0.05$) on the use of range with greater number of older hens found to use the range compared to their younger counterparts (Figure 4.8). This implied that at the time of this study, range use increased as the hens grew older.

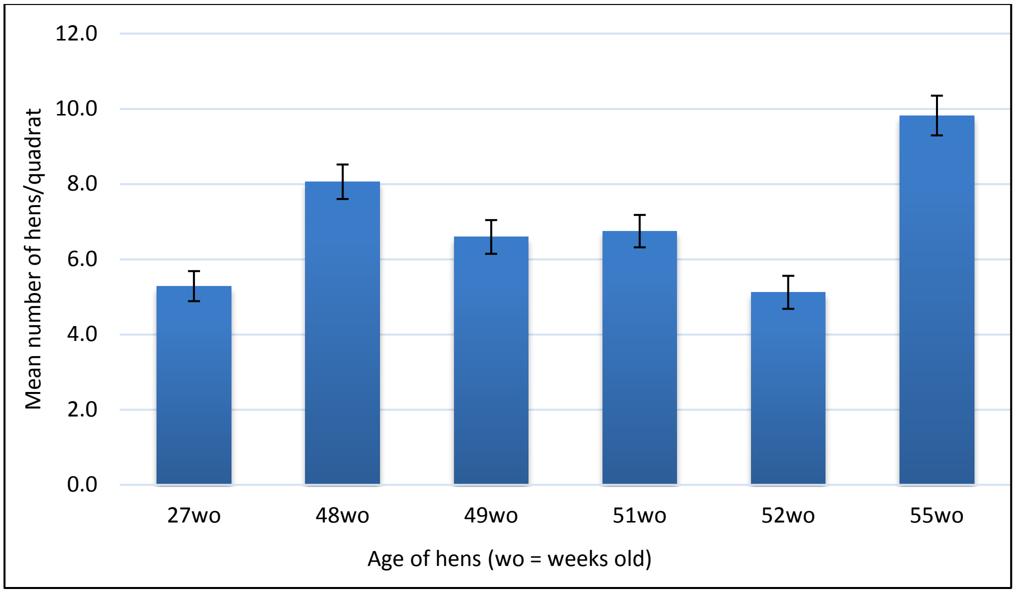


Figure 4.8 Showing that the (±SEM) number of hens/quadrat in the range were more likely to increase as the hens got older.

Effect of flock size on the use of range

Flock size was treated as a covariate in the GLM analysis and the result showed that flock size interacted significantly with zone ($F_{2,4198} = 31.68$, $p < 0.05$), suggesting that the number of hens found within the apron, enriched and outer range zones depended on the number of hens in the flock. Generally, there were more hens in the apron compared to the enriched and outer range zones (Figure 4.9) and there were greater number of hens/quadrats in the smaller flocks compared to their larger counterparts in all the outdoor zones. Group sizes were not balanced out between the flocks and for this reason, no further *post hoc* test was carried out to compare the flocks that differed significantly from the others.

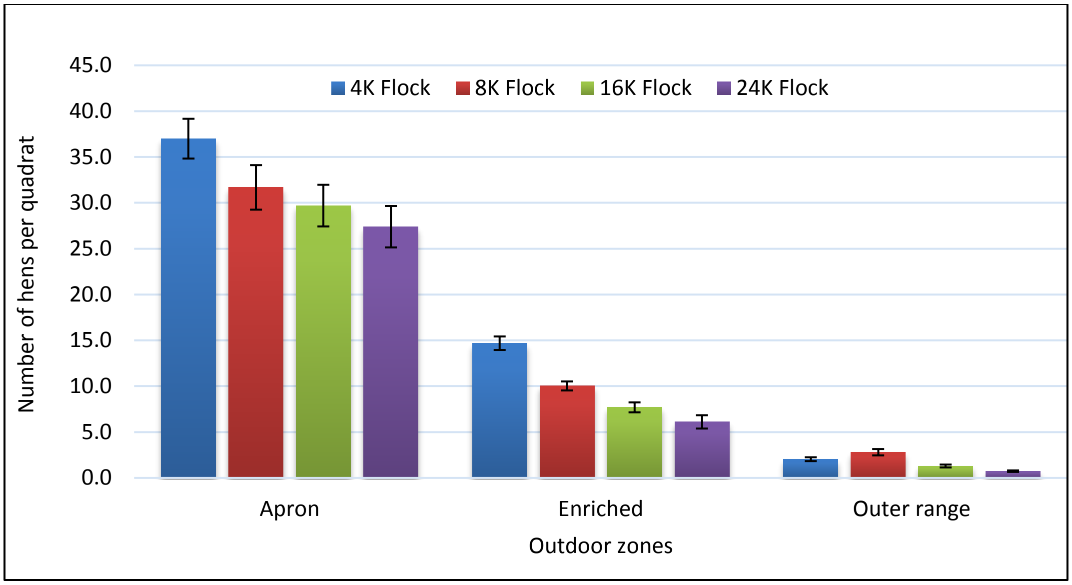


Figure 4.9 Showing the mean (±SEM) number of hens/quadrat in different outdoor zones in different group sizes. Hens in smaller flocks used all the outdoor zones more compared to their counterparts in larger flocks. (K = thousand).

Nearest neighbour distance of the hens in the range

The results of the Pearson's product-moment correlation analysis carried on the number of hens in the range and their NND showed that there was a significant inverse relationship between range use and the NND of the hens (r = - 0.197, p < 0.001). Further tests compared the use of the three outdoor zones with the NND of the hens in the respective areas showed that the relationship between the two variables was significant only in the outer range zone (r = + 0.104, p < 0.01), but not in the apron (r = - 0.096, p > 0.05) and enriched (r = + 0.057, p > 0.05) areas. These results implied that the NND of the hens decreased generally as the number of hens in the range increased. The only part of the range where significant relationship was detected between hen number and NND was the outer range, but this relationship was in a positive direction with an increase in the number of hens in the outer range being associated with increased NND.

In the fitted NND model, the effects of zone, strain, pop hole, age and flock size on the NND of the hens were analysed in the GLM and of these, zone, pop hole and age were included in the fitted model as the significant variables (See Appendix). On the other hand, strain and flock size were excluded in the fitted model as they did not influence the NND of the hens in the range. The results of the GLM analysis showed that the NND of the hens was influenced by their location (zone) in the range. The mean NND of the hens differed significantly ($F_{2,2865} = 7.63$, $p < 0.05$) between the apron, enriched and outer range zones with the hens in the outer range (5.57 ± 0.151 m) found to have the greatest NND, the least NND recorded in the apron zone (1.62 ± 0.051 m) and the intermediate NND recorded in the enriched zone (2.40 ± 0.083 m). The above result indicated that the distances between hens was not similar in all the outdoor zones and increased with increasing distance from the shed regardless of the hen age, strain, flock size and the location of the pop holes on the sides of the sheds.

Effect of pop hole location on the NND of the hens

Location of the pop holes on the sides of the sheds had a significant effect on the NND of the hens in different areas of the range. Pop hole location interacted significantly with zone ($F_{2,2865} = 4.686$, $p = 0.009$) and it indicated that the NND of the hens in single and double-sided sheds varied between and within the three outdoor locations. The mean NND of the hens differed significantly between the two exit types in the apron ($F_{1,958} = 4.153$, $p = 0.042$) and enriched ($F_{1,958} = 6.562$, $p = 0.011$) zones but not in the outer range area ($F_{1,958} = 1.873$, $p = 0.171$) and this indicated that the hens from double sided sheds had greater NND compared to their counterparts from single sided sheds. The mean NND of the hens in the three outdoor zones also differed significantly between the single ($F_{2,957}$ = 173.089, p < 0.001) and double sided ($F_{2,1917}$ = 249.489, p < 0.001) sheds and the results showed that the hens from both access types had greatest NND in the outer range, least NND in the apron and intermediate NND in the apron zone (Figure 4.10).

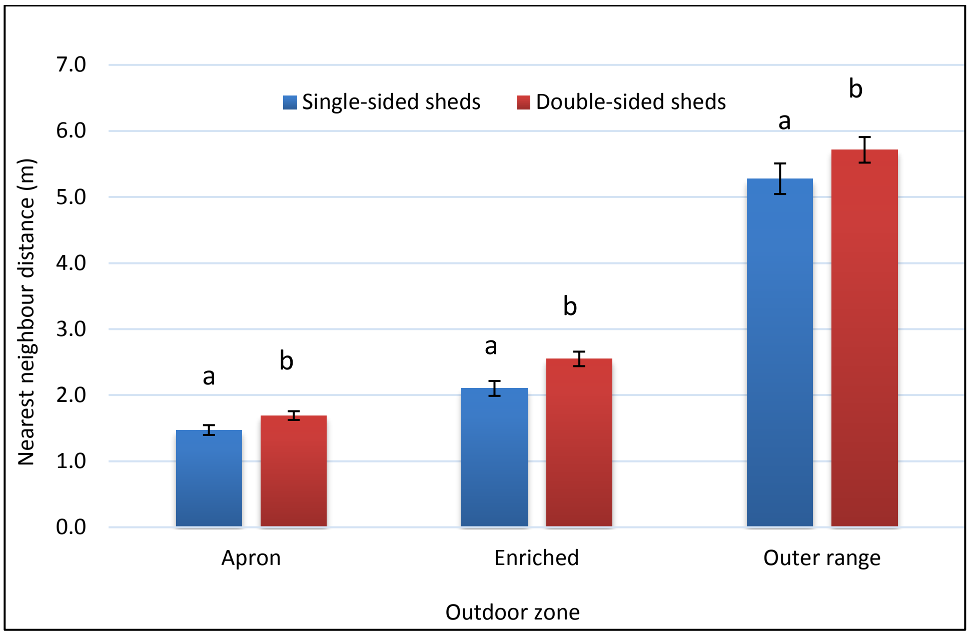


Figure 4.10. Showing the mean (±SEM) NND of the hens in apron, enriched and outer range zones of single and double sided sheds. The hens from double sided sheds had greater NND in all the zones. [a,b] Means that difference between exit types with different superscripts are significantly different (p < 0.001).

Effect of age on the NND of the hens

The results showed that age of the hens had a significant effect on their NND in the different outdoor zones. There was a statistically significant two-way interaction between the age and zone ($F_{1,2865} = 25.293$, $p < 0.05$), indicating that the NND of the hens of different ages depended on the outdoor zone where they were found and vice versa. The difference between the mean NND of the hens of different ages was significant in the apron ($F_{5,954} = 12.806$, $p < 0.001$), enriched ($F_{5,954} = 10.694$, $p < 0.001$) and outer range ($F_{5,954} = 16.459$, $p < 0.001$) zones and this showed that NND of the hens varied within all the zones. Also the difference between mean NND of the hens in different zones was significantly different for the 27wo ($F_{2,477} = 35.151$, $p < 0.001$), 48wo ($F_{2,477} = 64.919$, $p < 0.001$), 49wo ($F_{2,477} = 57.049$, $p < 0.001$), 51wo ($F_{2,477} = 92.230$ $p < 0.001$), 52wo ($F_{2,477} = 125.241$, $p < 0.001$) and 55wo ($F_{2,477} = 86.779$, $p < 0.001$) hens. The results of the interactions showed that the NND of the hens increased with age and with increased distance from the shed (Figure 4.11).

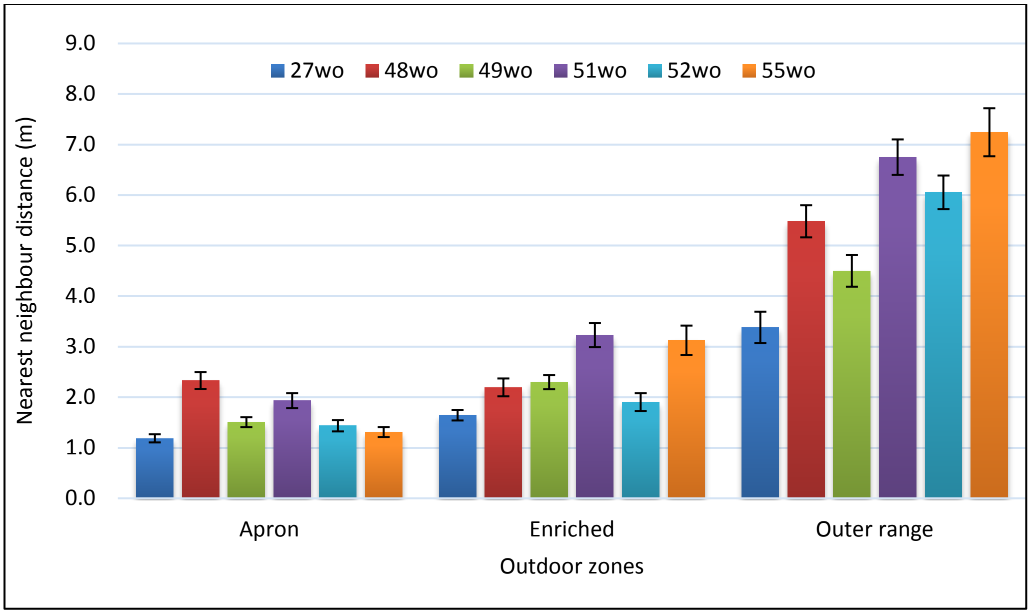


Figure 4.11 Showing the mean (±SEM) NND of the hens of different ages recorded in the apron, enriched and outer range zones. The mean NND of the hens increased with age and as the distance from the shed increased.

Feather condition of the hens in the range

The outcome of the step-wise feather condition model/procedure showed that out of the 6 explanatory variables tested, only body part, strain, zone and age were included in the fitted model as they had significant effects on the feather condition of the hens in the range (See Appendix). The remaining two facts, pop hole, and flock size were excluded from the final model on the basis that they did not influence the feather condition of the hens.

The feathers from four selected body parts of the hens was scored based on their degree of damage or no damage and the result of the analysis showed that the degree of feather loss in the hens was significantly different between the four body parts ($F_{3,11496} = 12.545$, $p < 0.001$). The side feathers were found to have the least score with the greatest score recorded for the neck feathers followed by the chest and back feathers respectively. Being that higher feather score indicated greater feather loss or damages, the result further suggested that of all the body parts scored, the side of the hens had best or intact feathers whereas the neck region had worst feathers followed by the chest and back areas respectively (Figure 4.12).

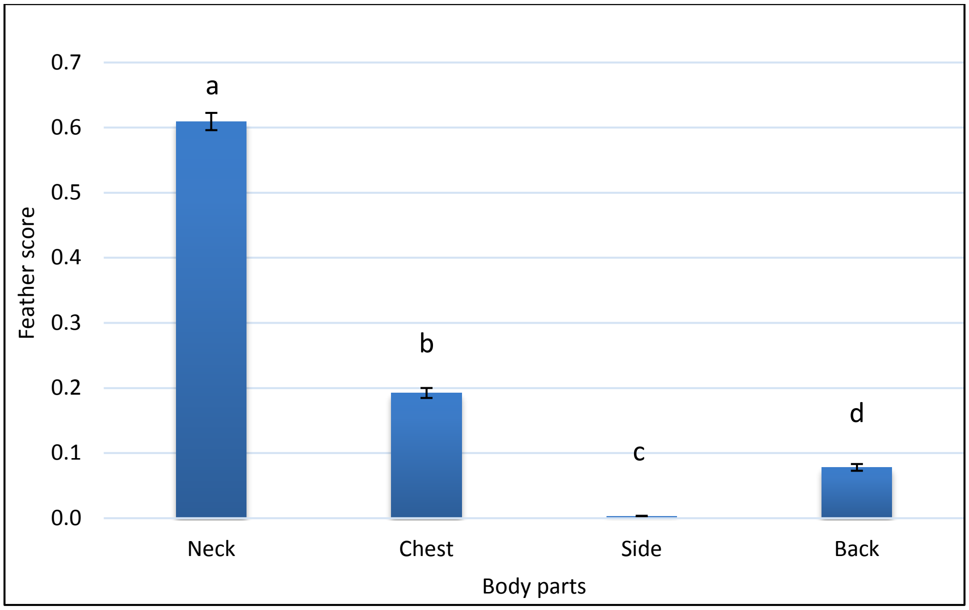


Figure 4.12. The mean (±SEM) feather scores differed significantly between the neck, chest, side and back regions of the hens with the side feathers found to be the most intact. [a,b,c,d] Means for body parts with different superscripts are significantly different ($p < 0.001$).

The location of the hens in the range at the time of the study had a significant effect on the overall feather condition of the hens with difference between the feather of the hens in different outdoor zones (the apron, enriched and outer range areas) found to be significant ($F_{2,11496} = 738.674$, $p < 0.001$). The results of the descriptive statistics and *post hoc* tests showed that the mean feather score of the hens in the outer range was (0.058 ± 0.005) and significantly less compared to that of their counterparts in the enriched (0.209 ± 0.008) and apron (0.395 ± 0.010) areas and that the feather score of the hens in the enriched zone was significantly less than that of the apron bound hens. These results suggested that the hens found in the outer range had the best overall feather cover, but the feather quality of the hens decreased towards the shed with the hens nearest to the shed found to have least feather cover. There was a significant two-way interaction between body part and zone ($F_{6,11496} = 258.616$, $p < 0.05$), indicating that feather scores of the four body parts of the hens varied within and between the three outdoors. The mean feather score of the neck ($F_{2,2877} = 538.376$, $p < 0.001$), chest ($F_{2,2877} = 78.273$, $p < 0.001$), side ($F_{2,2877} = 3.515$, $p < 0.05$) and the back feathers ($F_{2,2877} = 192.833$, $p < 0.001$) differed significantly between the apron, enriched and outer range zones. The mean of feather score differed significantly between the four body parts in the apron ($F_{3,3836} = 995.838$, $p < 0.001$), enriched ($F_{3,3836} = 413.320$, $p < 0.001$) and outer range ($F_{3,3836} = 86.892$, $p < 0.001$) zones with the mean score of side feathers being the least, followed by the back, chest and neck feather respectively. This result showed that the feather score of all the body parts of the hens were found to be greatest in the apron bound hens and decreased with increased distance from the shed (Figure 4.13).

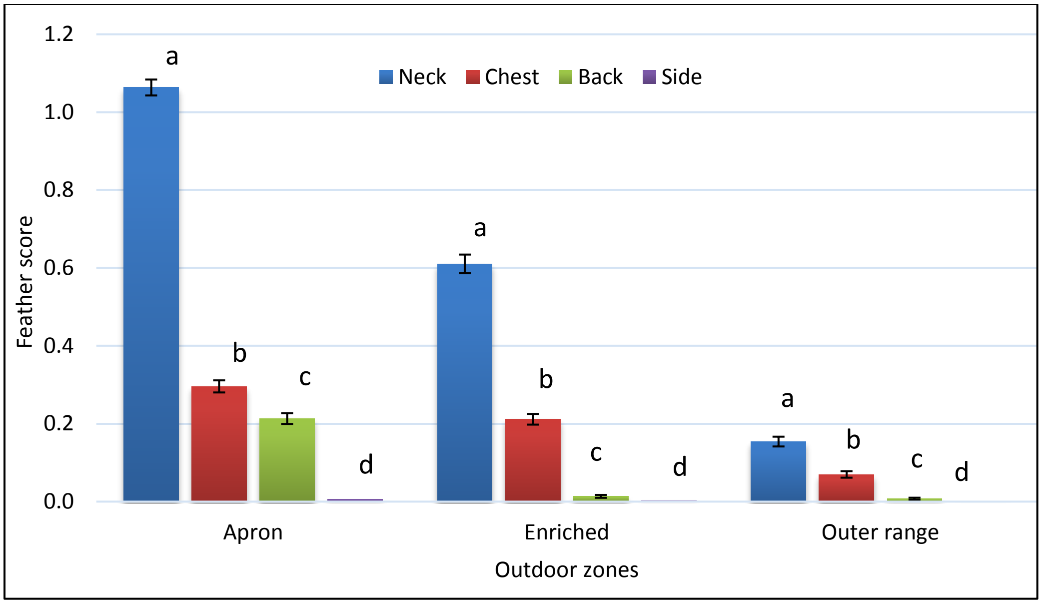


Figure 4.13. The mean (±SEM) feather score of the hens was greatest for the neck region, followed by the chest, back and side areas for all the outdoor zones. [a,b,c,d] Means that the difference between body parts in a zone with different superscripts are significantly different ($p < 0.05$).

Effect of strain on the feather condition of the hens

Strain had a significant effect on the quality of the feather cover of the body parts of the hens shown by the significant interaction between body part and strain ($F_{3,11496} = 6.861$, $p < 0.001$). This indicated that the condition of the feathers from most of the four body parts of the hens varied between the hen strains. The neck ($F_{1,2878} = 5.441$, $p < 0.001$), chest ($F_{1,2878} = 26.057$, $p < 0.001$) and back ($F_{1,2878} = 11.606$, $p < 0.001$) feather conditions were found to differ significantly between the two strains, whereas condition of the side feathers was similar in both Hyline and Lohmann Brown hens ($F_{1,2878} = 5.441$, $p > 0.05$). The results of the interaction followed a similar pattern as the overall feather score of the hens, with evidence that the Hyline hens had better plumage cover in all the scored body parts compared to their Lohmann Brown counterparts (Figure 4.14).

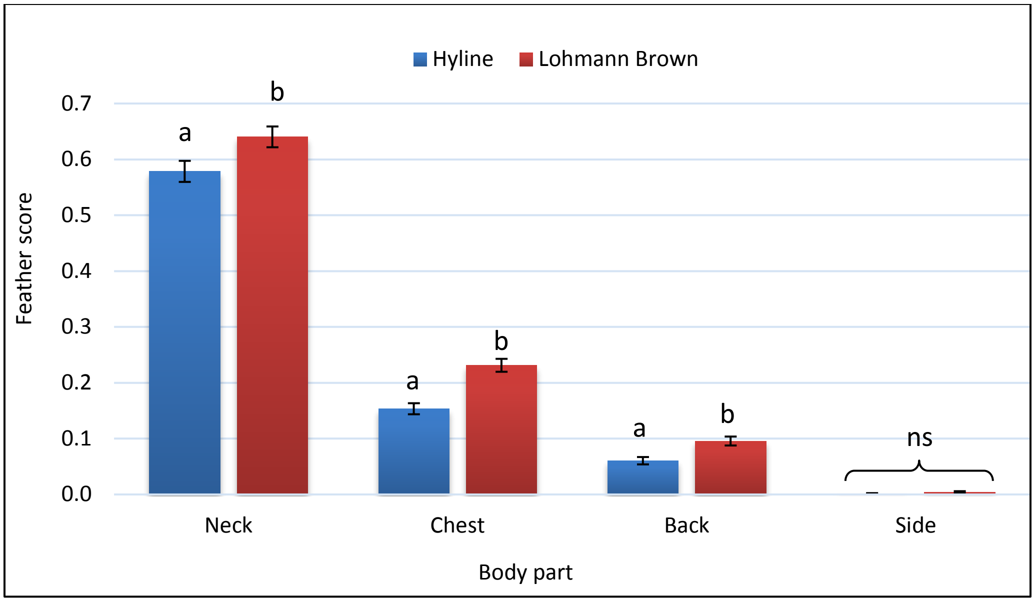


Figure 4.14. Showing that the mean (±SEM) feather score of the neck, back, chest and sides areas of both Hyline and Lohmann Brown hens differed significantly. [a,b] Means that the difference between strains with different superscripts are significantly different ($p < 0.001$). [ns] Means that the difference between strains are not significantly different ($p > 0.05$)

Effect of age on the feather condition of the hens

The feather score of the hens was expected to increase (become worse) with increased age but it was not the case as the feather condition of the hens appeared to improve during the study and this suggested that the older hens had unexpectedly better feather quality compared to their younger counterparts. There was a significant interaction between body part and age of the hens ($F_{3,11496}$ = 258.616, $p < 0.05$) suggesting that the feather scores of the four body parts of the hens varied with age of the hens. The difference between the feather score of the different age groups was significant in the neck ($F_{5,2874}$ = 8.201, $p < 0.001$), chest ($F_{5,2874}$ = 11.914, $p < 0.001$), side ($F_{5,2874}$ = 2.917, $p < 0.05$) and back ($F_{5,2874}$ = 6.805, $p < 0.001$) regions of the hens. Also, the difference between the feather scores of the body parts was significant for the 27wo ($F_{3,1916}$ = 205.776, $p < 0.001$), 48wo ($F_{3,1916}$ = 225.315, $p < 0.001$), 49wo ($F_{3,1916}$ = 166.849, $p < 0.001$), 51wo ($F_{3,1916}$ = 180.024, $p < 0.001$), 52wo ($F_{3,1916} = 241.557$, $p < 0.001$) and 55wo ($F_{3,1916} = 129.679$, $p < 0.001$) hens. The results implied that the sides of the hens had best feather cover followed by the back, chest and neck regions for all age groups and also that the older hens showed signs of improved feather compared to their younger counterparts in all the body parts scored (Figure 4.15).

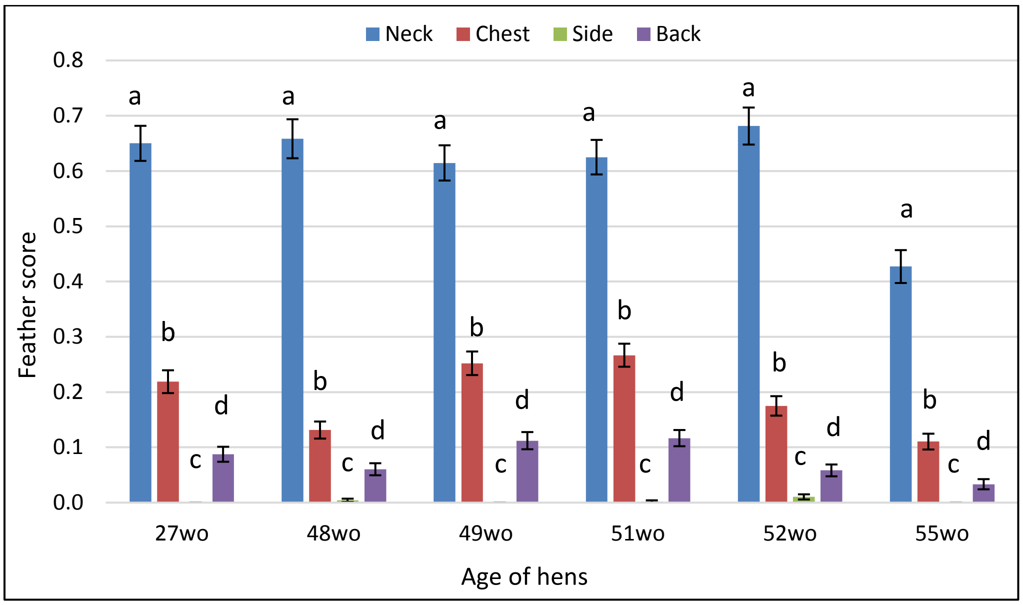


Figure 4.15 Showing that the mean (±SEM) feather score of all ages of hens differed significantly between the neck, back, chest and sides areas. [a,b,c,d] Means that the body parts of age groups with different superscripts are significantly different ($p < 0.001$).

Behaviour of the hens in the range

A GLM analysis was carried out on each of the 5 behavioural categories recorded during this study and the procedure tested the effect of zone, strain, pop hole, age and flock size on each of the behavioural categories. The factors retained in the fitted behaviour model were zone and strain for the resting and appetitive/foraging categories whereas the fitted model for locomotion consisted of zone as the only significant factor (See Appendix).

The 5 behaviour categories recorded during this study consisted of the following behaviours; resting (standing, sitting, lying and perching behaviours); foraging (ground pecking, foraging and ground scratching); locomotion (walking, running and flying); comfort (preening, dust bathing, stretching, wing flapping and shaking) and aggressive behaviours. The results of the descriptive statistics showed that the most recorded behaviour in the range was foraging (42.73 ± 1.64) followed by resting (27.56 ± 1.69), locomotion (25.99 ± 1.09), comfort (3.68 ± 0.84) and aggression (0.04 ± 0.04) respectively. This indicated that while the current study lasted, the hens engaged most in foraging behaviour followed by resting, locomotion and comfort respectively, with aggressive behaviour being the least recorded activity in the range.

Evidence showed that location of the hens in the range influenced most of the recorded behaviours, with zone found to have significantly effect on the proportion resting ($F_{2,135} = 52.256$, $p < 0.001$), foraging ($F_{2,132} = 4.777$, $p < 0.05$) and locomotory ($F_{2,138} = 9.384$, $p < 0.001$) behaviours but no effect of location was detected in the proportion of comfort ($F_{2,129} = 0.962$, $p = 0.385$) and aggressive ($F_{2,129} = 0.088$, $p = 0.916$) behaviours of the hens. The results of the descriptive statistics indicated that the hens were more likely to perform resting behaviour in the apron strip and least in the outer range zone whereas foraging and locomotory behaviours were recorded most in the outer range compared to the apron and enriched areas of the range (Figure 4.16). The results also showed that the proportions of comfort and aggressive behaviours did not vary between the apron, enriched and outer range areas of the range.

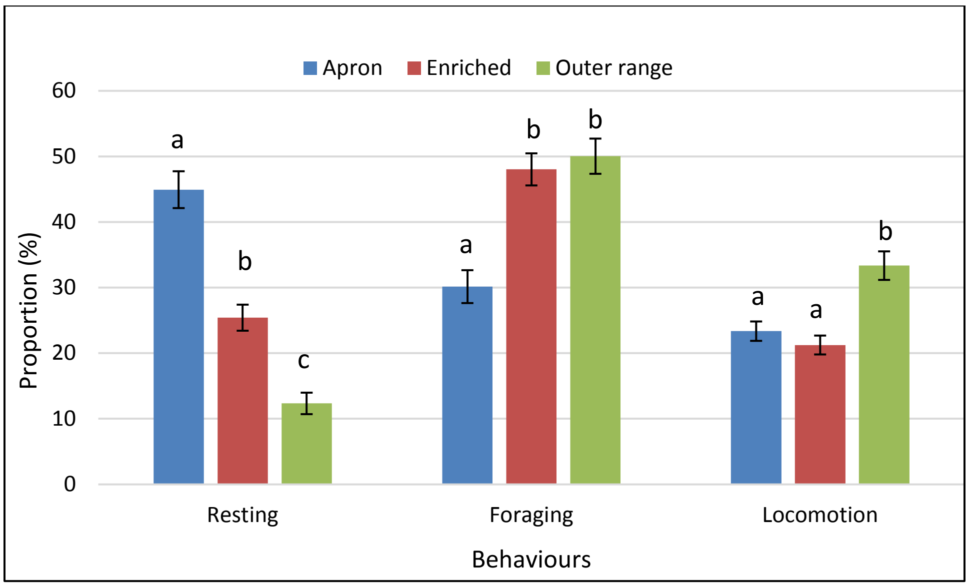


Figure 4.16. Mean (±SEM) proportion of resting, foraging and locomotory behaviours of the hens in the apron, enriched and outer range zones. [abc] Means that behaviours in a zone with different superscripts are significantly different ($p < 0.05$ for foraging and $p < 0.001$ for resting and locomotion).

Effect of age on the behaviour of the hens

The behaviour of the hens varied between different ages and this was seen in the significant two-way interaction between zone and age of the hens in the proportion of appetitive/foraging ($F_{3,132} = 3.632$, $p < 0.05$) and locomotory ($F_{3,129} = 4.190$, $p < 0.05$) behaviours but this effect was not detected for resting ($F_{2,129} = 0.158$, $p = 0.854$), comfort ($F_{2,129} = 0.689$, $p = 0.504$) and aggressive ($F_{2,129} = 0.495$, $p = 0.611$)

behaviours. This suggested that the proportion of foraging and locomotory behaviours performed by different age groups in the range depended on their location with both behaviours found to occur most in the outer range, followed by the enriched and apron zones respectively for all age groups. The proportion of foraging behaviour differed significantly between different ages of hens in the outer range zone only ($F_{5,42} = 4.724$, $p < 0.05$) but not in the apron ($F_{5,42} = 1.680$, $p = 0.161$) and enriched ($F_{5,42} = 1.338$, $p = 0.267$) areas of the range. This indicated that the occurrence of foraging behaviour in the outer range zone depended on the age of the hens but this did not apply to the hens found in the apron and enriched zones. The hens found in the outer range area more likely to engage in foraging activities as their age increased (Figure 4.17). Also, the occurrence of foraging behaviour between the three outdoor zones was found to differ significantly for all the age groups i.e. the 27wo ($F_{2,21} = 3.525$, $p < 0.05$), 48wo ($F_{2,21} = 13.874$, $p < 0.001$), 49wo ($F_{2,21} = 3.507$, $p < 0.05$), 51wo ($F_{2,21} = 6.995$, $p < 0.05$), 52wo ($F_{2,21} = 4.829$, $p < 0.05$) and 55wo ($F_{2,21} = 6.275$, $p < 0.05$) hens. This result indicated that the occurrence of foraging behaviour varied between the apron, enriched and outer range zones for all hen ages and was found to increase as the distance from the shed increased except for the 27wo hens.

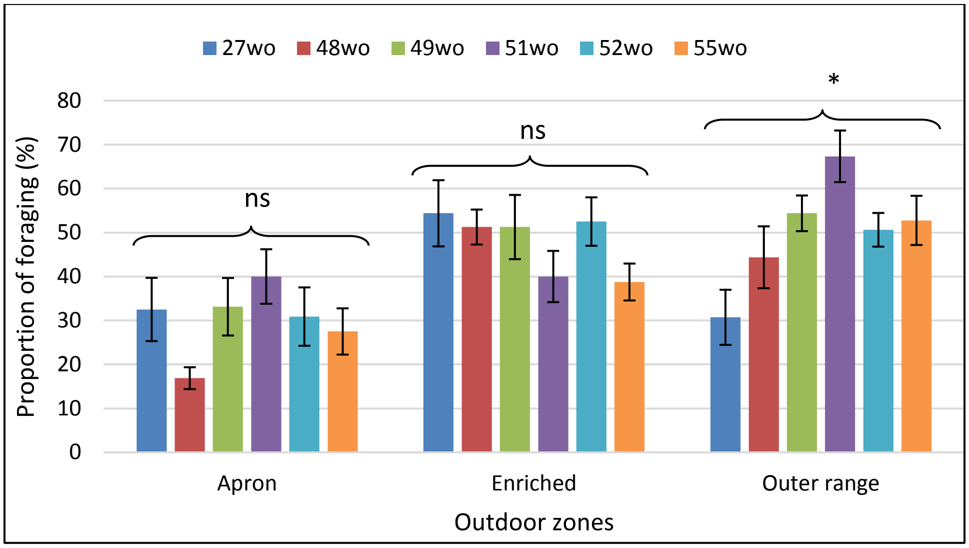


Figure 4.17 Foraging behaviour occurred most in the outer range for all the age groups and was found to increase with age of the hens in the outer range zone but not in the apron and enriched areas. * Means that proportion of foraging behaviour between age groups is significantly different ($p < 0.05$). ns Means that difference in the proportion of foraging behaviour between age groups is not significant ($p > 0.05$).

The proportion of locomotory behaviour recorded outdoors was found to differ significantly between different age groups in the enriched ($F_{5,42} = 2.983$, $p < 0.05$) and outer range ($F_{5,42} = 3.018$, $p < 0.05$) zones but not in the apron area ($F_{5,42} = 1.035$, $p = 0.410$) and this implied that hens of different ages showed variations in the proportion of movement activities they performed in the enriched and outer range zones only but not in the apron area. The results also showed that locomotion increased as the enriched zone bound hens got older but decreased as the hen ages increased in the outer range area. Also, the proportion of locomotion recorded between the three outdoor zones differed significantly in the 27wo ($F_{2,21} = 16.092$, $p < 0.001$), 49wo ($F_{2,21} = 4.406$, $p < 0.05$) and 55wo ($F_{2,21} = 8.640$, $p < 0.05$) hens but did not differ in the 48wo ($F_{2,21} = 2.561$, $p = 0.101$), 51wo ($F_{2,21} = 0.611$, $p = 0.552$) and 52wo ($F_{2,21} = 0.511$, $p = 0.607$) groups. There was a general increase in the locomotive activities of most hens in the range as the distance from the shed increased which suggested that the hens were more likely to perform move in the outer range zone compared to the enriched and apron zones (Figure 4.18).

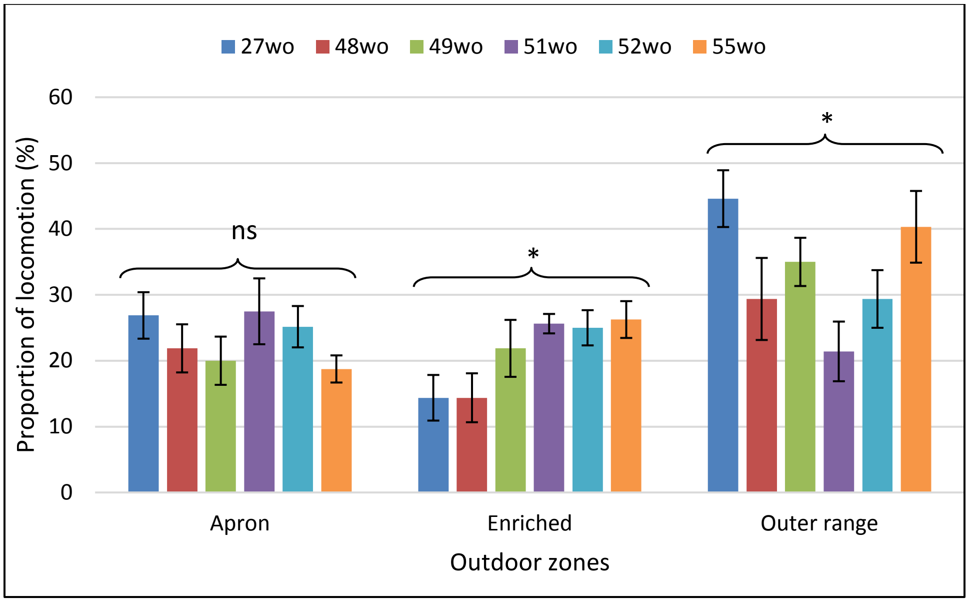


Figure 4.18. The hens in the outer range were more likely to engage in locomotion but the older hens tended to reduce their movements in this part of the range. Movement of the hens in the enriched zone appeared to increase as they got older. * Means that difference in the proportion of locomotory behaviour between age groups is significant ($p < 0.05$). ns Means that difference in the proportion of locomotory behaviour between age groups is not significant ($p > 0.05$).

Effect of pop hole location on the behaviour of the hens

There was a significant two-way interaction between zone and pop hole location in the occurrence of resting ($F_{3,129} = 3.344$, $p < 0.05$) and foraging ($F_{3,132} = 2.748$, $p < 0.05$) behaviours but this effect was not seen in the proportion of locomotion ($F_{2,131} = 2.834$, $p = 0.062$), comfort ($F_{2,129} = 1.157$, $p = 0.318$) and aggression ($F_{2,129} = 0.013$, $p = 0.987$). This showed that the proportion of resting and foraging behaviours between the apron, enriched and outer range zones depended on whether the pop hole was located on single or two sides of the shed. The difference in the proportion of resting behaviour recorded between the single and double-sided sheds was significant in the enriched zone ($F_{1,46} = 4.472$, $p < 0.05$) but not in the apron ($F_{1,46} = 0.013$, $p = 0.910$) and outer range ($F_{1,46} = 1.021$, $p = 0.317$) zones which indicated that the occurrence of resting behaviour recorded in both the single and double-sided flocks varied in the enriched zone only but was similar in the apron and outer range areas. The mean proportion of resting behaviour between the three outdoor zones was significantly different for both single ($F_{2,45} = 18.602$, $p < 0.001$) and double sided ($F_{2,93} = 39.130$, $p < 0.001$) sheds with the hens in the apron found to be more likely to engage in resting behaviour followed by the enriched and outer range zones in both type of exits (Figure 4.19).

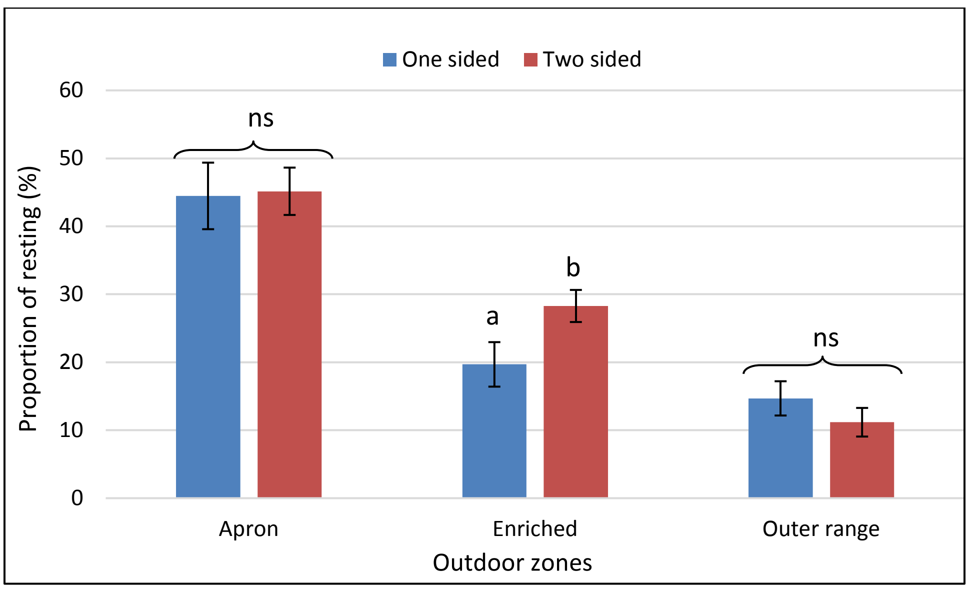


Figure 4.19. Resting behaviour occurred most in the apron zone, least in the outer range and intermediate in the enriched area and the hens housed in the sheds with double sided exit types were more likely to rest in the enriched zone. [ab] Means that the different in between exit times in a zone with different superscripts is significantly different ($p < 0.05$). [ns] Means that there was no significant different between exit types within a zone ($p > 0.05$).

The mean proportion of foraging behaviour did not differ significantly between the single and double sided sheds in all the outdoor areas i.e. apron ($F_{1,46} = 0.271$, $p = 0.605$), enriched ($F_{1,46} = 1.249$, $p = 270$) and outer range ($F_{1,46} = 0.417$, $p = 0.521$) zones, indicating that the proportion of foraging behaviour recorded between the single and double-sided flocks but have similar values in all the outdoor zones. This further showed that there were no variations in the occurrence of foraging between the two exit types in the entire range. On the other hand, the proportion of foraging behaviour recorded between the apron, enriched and outer range zones differed significantly in the single ($F_{2,45} = 8.598$, $p < 0.05$) and double sided ($F_{2,93} = 10.490$, $p < 0.001$) exit types, which meant that the hens housed in single exit type performed more foraging behaviour in the outer range, followed by the enriched and apron zones compared to the ones in double sided houses (Figure 4.20).

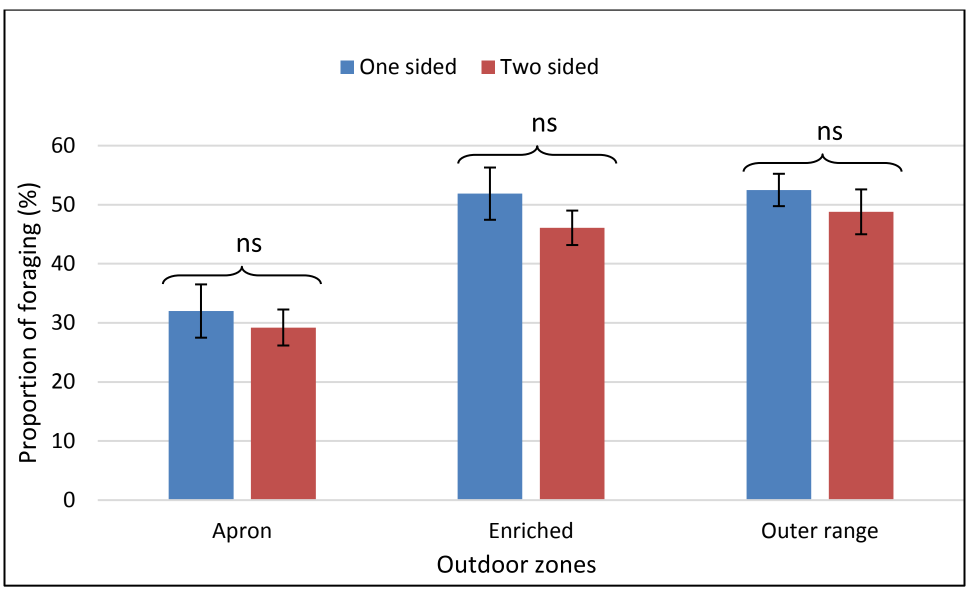


Figure 4.20. Foraging behaviour was recorded most in the outer range and the hens housed in sheds with single sided pop holes were more likely to perform foraging behaviour in all the outdoor zones, although the differences between them are not significant. [ns] Means that the difference in foraging behaviour between the single and double sided sheds is not significant ($p > 0.05$).

Effect of strain on the behaviour of the hens

The strain of the hens as found to have a significant effect on the proportion of resting ($F_{1,135} = 5.565$, $p < 0.05$) and foraging ($F_{1,135} = 6.646$, $p < 0.05$) behaviours but not on the proportion of locomotory ($F_{1,129} = 0.132$, $p = 0.717$), comfort ($F_{1,129} = 0.687$, $p = 0.409$) and aggressive ($F_{1,129} = 0.260$, $p = 0.611$) behaviours recorded in the range. The results showed that the Hyline rested more than their Lohmann Brown counterparts but the Lohman Brown hens were more likely to engage in greater foraging behaviour in the range (Figure 4.21).

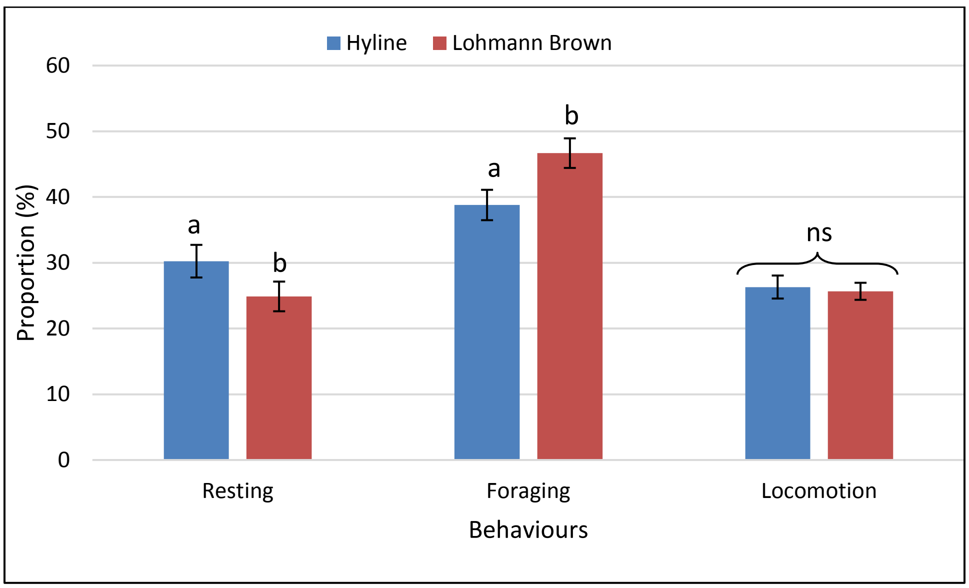


Figure 4.21 Mean (±SEM) proportion of resting and foraging behaviours of the Hyline and Lohmann Brown hens in the range with the Hyline hens more likely to rest and the Lohman Brown hens showing greater foraging activities. [abc] Means that strains with different superscripts are significantly different ($p < 0.05$). [ns] Means that the difference between strains is not significant different for locomotory behaviour ($p > 0.05$).

There was a significant interaction between strain and zone in the proportion of resting ($F_{2,135} = 3.525$, $p < 0.05$) and foraging ($F_{2,132} = 3.501$, $p < 0.05$) behaviours but this effect was not detected in the proportion of locomotion ($F_{2,129} = 0.630$, $p = 0.534$), comfort ($F_{2,129} = 0.630$, $p = 0.534$) and aggression ($F_{2,129} = 0.630$, $p = 0.534$). This result indicated that the occurrence of resting and foraging behaviours by the Hyline and Lohmann Brown hens varied between the three outdoor locations with greater resting behaviour recorded in the apron, followed by the enriched and outer range zones respectively (Figure 4.22). The mean proportion of resting behaviour recorded between the three outdoor zones was significant for both Hyline ($F_{2,69} = 37.949$, $p < 0.001$) and Lohmann Brown ($F_{2,69} = 20.727$, $p < 0.001$) hens but the difference between the proportion of resting behaviour performed by the Hyline and Lohmann Brown hens was not significant in the apron ($F_{1,46} = 3.432$, $p = 0.070$), enriched ($F_{1,46} = 1.104$, $p = 0.299$) and outer range ($F_{1,46} = 0.289$, $p = 0.593$) zones. This implied that though the occurrence of resting behaviour differed between outdoor zones, there was no strain differences in its occurrence within each zone.

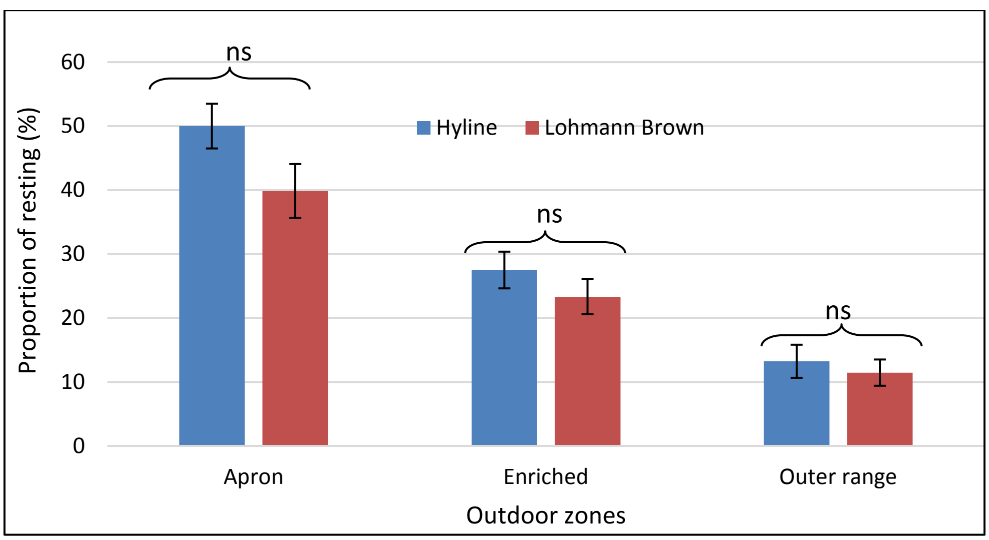


Figure 4.22. Showing that the difference between the proportion of resting behaviour performed by Hyline and Lohmann Brown hens was significant between zones but not within them. [ns] Means that difference in resting behaviour between hen strains in a zone is not significantly different ($p > 0.05$).

For foraging behaviour, the difference in its mean proportion recorded between the Hyline and Lohmann Brown strains was significant in the outer range zone only ($F_{1,46} = 8.916$, $p < 0.05$) but not in the apron ($F_{1,46} = 3.425$, $p = 0.071$) and the enriched ($F_{1,46} = 0.002$, $p = 0.967$) areas. The proportion of foraging behaviour recoded differed significantly between the three outdoor zones for the Hyline ($F_{2,69} = 11.028$, $p < 0.001$) and Lohmann Brown ($F_{2,69} = 11.039$, $p < 0.001$) hens. The results implied that foraging behaviour was recorded most in the outer range, followed by the enriched and apron zones respectively and this pattern of occurrence was seen in the two hen strains (Figure 4.23). There was also evidence that the Lohmann Brown hens were more likely to engaged in foraging behaviour than their Hyline counterparts in the outer range.

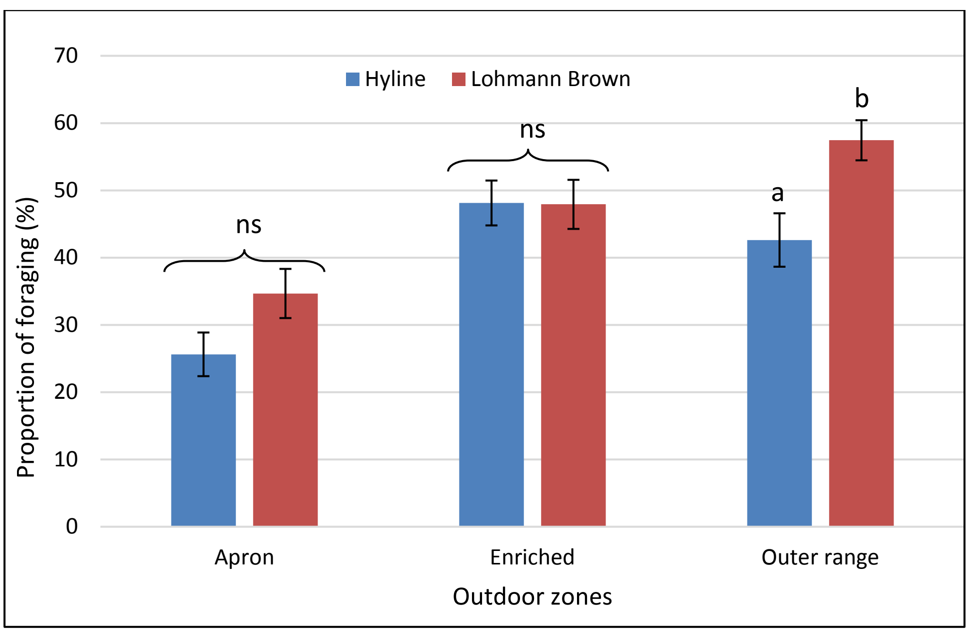


Figure 4.23. Foraging behaviour occurred most in the outer range zone and the Lohmann Brown were more likely to forage in the outer range but this difference was not seen in the apron and outer range areas. [ab] Means that strains with different superscripts in a zone is significantly different ($p < 0.05$). [ns] Means that strains in a zone are not significantly different ($p > 0.05$).

Summary of the discussions

The result of the current study was broadly in line with other studies that investigated the use of range by free-range laying hens, especially the report that a smaller proportion of the hens in the flocks used the range in larger flocks (Hegelund *et al*. 2005; Kijlstra *et al*. 2007; Whay *et al*. 2007). The current study also found that there was a skewed distribution of hens in the range with majority of the hens found to stay in the apron zone and associated decline in the number of hens with increasing distance from shed (Keeling *et al*. 1988; Nicol *et al*. 2003; Nagle and Glatz, 2012), making outer range the least utilized outdoor area. The current study also found that there was a decline in range use in colder conditions (e.g. Hegelund *et al*. 2005; Richards *et al*. 2011; Gilani *et al*. 2014) and that the areas of the range with highest hen number (apron) had the least NND compared to the least utilized area (outer range). The use of distant part of the range was found to be associated with improved feather condition in the hens (e.g. Nicol *et al*. 2003; Horton, 2006; Lambton *et al.* 2010). The current study also found that the sampling techniques (transect and quadrat methods) and additional measures (head counts, NND measurement, behavioural observations and feather scoring in the three outdoor zones) utilized for the data collection, provided detailed information on the use of range as well as the potential benefits of the ranging pattern, behaviour and the NND on the feather condition of the hens.

Effects of temperature and RH on the use of range

Different climatic conditions e.g. temperature, RH, wind and rainfall have been reported to influence the use of range in flocks of free-range laying hens (Nicol *et al*. 2003; Hegelund *et al*. 2005; Richards *et al*. 2011, 2012; Nagle and Glatz, 2012; Gilani *et al*. 2014) and these reports are in line with the findings of the current study. In the current study, it was found that temperature and RH varied through the study period and this was in line with the prevailing seasonal changes. Temperature and RH had significant effects on the number of hens found in the range with an increase in temperature found to result in greater number of hens in the range, whereas an increase in the RH was associated with reduced outdoor use.

Nicol *et al*. (2003) studied the risk factors for feather pecking in 50 matched concurrent flocks of laying hens (with and without feather pecking) in the United Kingdom and reported that the current weather conditions at the time of study had significant influence on range use with the hens found to respond differently to the weather variables. They found that farmers reported that the hens in the feather pecking flocks used the range more when the weather was calm and dull (34%) whereas sunny (14.7%), wet (8.1%) and cold (19.3%) conditions were associated with reduced number of hens in the range. They also reported similar ranging pattern (for each weather variable) in the control flocks (non-feather pecking flocks), where more hens were recorded out of the shed.

Richards *et al*. (2011) monitored the use of pop holes in commercial free-range laying hens using the RFID technology and found that the mean daily temperature, wind speed, rainfall, and hours of sunshine had significant influence on the pop hole activity of the hens throughout their production cycle. They reported that daily temperature had the largest effect on the pop hole activity with increased pop hole use of 0.0418 for every degree increase in the temperature. They also reported that increase in wind speed and rainfall resulted in reduced pop hole usage whereas increased hours of sunshine encouraged pop hole activity in the hens.

Similarly, Richards *et al*. (2012) investigated the use of pop hole by hens with different keel fracture status during lay period and found that weather variables (temperature, daily rainfall, wind speed and wind direction) and keel score had significant effects on their pop hole usage. They utilized RFID transponders similar to Richards *et al*. (2011) above in monitoring pop hole activity over two consecutive lay periods in laying hens kept in four separate flocks and reported daily temperature, rainfall and wind speed had significant effects on the pop hole use of the hens. Temperature, wind speed and wind direction were found to have positive impacts whereas daily rainfall had a negative influence on pop hole usage and this suggested that more hens visited the pop holes when temperature and wind speed increased but reduced pop hole activity was associated with increased daily rainfall. The studies of Richards *et al.* (2011) and Richards *et al*. (2012) were centred on the pop hole activity of the hens but did not provide further details on whether the hens actually used the range or not. However, this limitation was down to the sampling technique used in the two studies, which identified the presence of the hens around the pop holes and not elsewhere. They argued that despite the lacking detail on range use, the measuring of pop hole activities in the hens using the RFID technology was an indicator of their movement and intention to use the range.

Hegelund *et al*. (2005) explored the effect of climatic factors i.e. temperature, wind, precipitation and season, on range use of 37 organic layer flocks housed at approximately 16 weeks of age and found that range use was affected by all the weather variables measured. They reported that temperature had a parabolic effect on range use where the number of hens in the range increased with rise in temperature until 17^{o}C (peak value) before decreasing with further increase in the ambient temperature. The maximum outdoor temperature recorded during the current study was 17.5^{o}C and based on the report of Hegelund *et al*. (2005), it was likely that the hens found this temperature comfortable and as a result used the range more.

Prior to the start of laying period (during rearing), hens are usually kept in warm and dry sheds, without direct wind impacts on them during which the hens may have acclimatized to this conditions before being let out to the range. They face unfamiliar and inclement weather conditions in the range (different from the indoor conditions) and in response to this, they may have decided to stay in the shed if they are likely to encounter unpleasant situations. While it was not possible to regulate the weather conditions in the range, Richards *et al*. (2011) and Pettersson *et al.* (2016) suggested that provision of additional shade or cover for the hens in the form of verandas is beneficial in limiting the impacts of weather variables on the hens which can in turn encourage more hens to use the range (e.g. Nicol *et al*. 2003; Hegelund *et al*. 2005; Nagle and Glatz, 2012).

Proportion of hens out of shed and their distribution in the range

On average, 12.5% of the hens in the flocks studied were found to use the range suggesting that a larger proportion of the hens (over 87% of the hens) did not use the range at any one time during the study, suggesting poor use of range (e.g. Bubier and Bradshaw, 1998; Mußlick *et al*. 2004; Hegelund *et al*. 2005, 2006; Harlander-Matauschek *et al*. 2006; Kijlstra *et al*. 2007; Whay *et al*. 2007) in the studied flocks. In the current study, most of the hens that used that range were found in the apron strip which is in line with the published scientific evidence (e.g. Keeling *et al*. 1988; Nicol *et al*. 2003; Nagle and Glatz, 2012) and associated with a decrease in hen number as the distance from the shed increased. This pattern of outdoor use seen in the current study suggested that outer range zone was the least utilized outdoor zone and that the enriched area was intermediately used at the time of the study. A similar pattern of outdoor use was seen in the quadrat measures of range use, which also revealed that the apron was the most utilized zone followed by the enriched and outer range zones respectively. The free-range system is designed in such a way that most of the important resources mentioned above (e.g. feeders, drinkers, nest boxes) are located in the shed thereby making the shed a relatively attractive part of the system compared to the range. One of the possible reasons for the high concentration of the hens around the shed may be because of the important resources located in the shed (nearest to the apron) which may be more attractive to them than the range itself as suggested by a recent study that reported that laying hens prefer to cluster around important resources e.g. shavings, perches, peat and nest boxes, feeders (Collins *et al.* 2011) mostly found in the shed, and coupled with the evidence that they show high motivation to feed frequently during the day (Nicol *et al*. 2009). However, Pettersson *et al*. (2016) suggested that the imbalanced attractiveness between the shed and the range can be resolved by improving the resources available in the range e.g. by providing cover (e.g. Hegelund *et al*. 2005; Harlander-Matauschek *et al*. 2006; Nagle and Glatz, 2012) instead of reducing the attractiveness of the shed. The close proximity to the shed by the hens may be related to the need for them to have quicker and easier access to the feed and water provided in the shed. Providing feed and water in the range may provide a solution to this problem but there seems to be potential issues with this e.g. feed and water contamination from wild birds and other predators may occur which can result in ill health or loss of hens. Also, the cost of providing feed and water resources in the range will likely increase the cost of production and may not be a feasible option for the farmers or even the consumers.

Also, the perceived risks or fear of predation in the range (e.g. Collias and Collias, 1967; Weeks and Nicol, 2006; Hartcher *et al.* 2015) may have resulted in the poor turn out in the range or the greater use of the apron zone. It has been suggested that this pattern of range use may be an anti-predator strategy (Nagle and Glatz *et al*. 2012), used by the hens to stay safe while out of the shed. Hartcher *et al.* (2015) reported that laying hens were likely to show signs of fearfulness when insufficient overhead cover was provided in the range and with insufficient range cover being associated with decreased protection from predators (Collias and Collias, 1967; Bubier and Bradshaw, 1998) and extreme weather conditions (Hoekstra *et al*. 1998), most of the hens observed in the current study were expected to stay in their shed. Based on the distances of the three outdoor zones, apron was the closest part of the range to the shed compared to the enriched and outer range zones and the hens in this zone are likely to travel the least distance into the shed when if they need to avoid threats and for this reason they may be discouraged from travelling to farther zones, especially if they have encountered predators.

The poor use of distant part of the range can be resolved by developing efficient enrichment strategies, with the potential to reduce fear responses in the hens. A typical example is the case of increased range use (including the farther areas of the range) associated with the provision of shelterbelts in the range (e.g. Nicol *et al*. 2009; Browne *et al*. 2010). The shelterbelts were argued to protect the hens from predation and also sheltered from the direct impact of rain, wind and direct sunshine. Zeltner and Hirt (2003) also found that hens were less likely to use the range when there was no cover provided outdoors and based on this, the poor use of range reported in this study may be a result of poor level of cover provided by the developing trees (at sapling stage). Cooper and Hodges (2010) suggested that saplings can increase range use but argued that greatest possible impact is at full or nearly full canopy cover.

The current study did not test the effect of motivation and health factors and their interactions (e.g. motivation X leg health) on the ability of the hens to use the range, have been suggested to influence range use in laying hens (Pettersson *et al*. 2016). A poor range use is likely when two or more factors counter each other e.g. hens may be motivated to use the range for foraging but may have impaired and limited ability to move and jump (Nasr *et al*. 2012) or reduce their pop hole activities due to painful keel bone fractures (Richards *et al*. 2012). Richards *et al*. (2012) found that a reduction in the pop hole use was associated with an increase in the severity of keel bone fractures in laying hens. Pettersson *et al*. (2016) further argued that poor house design and ill health can potentially prevent the highly motivated hens from accessing the range. On the other hand, healthy hens may lack the motivation to use the range due to other factors e.g. weather conditions which can result in poor use of range.

Dawkins *et al*. (2003) described the free-range system as a 'name only system' being that most of the birds housed in it do not leave their houses for the range. They went further to suggest that the poor use of range by the hens could be an indication that the hens do not like their environment. The current study did not explore whether same or different individuals used the range during the observations, but recent studies (Richards *et al.* 2011; Gebhardt-Henrich *et al*. 2014) have shown that majority of the hens (up to 90%) in free ranging flocks moved out of their shed at some point in their laying life. Their provided a good estimate of the value of the range to laying hens but it did not imply that this proportion of laying flock are expected to use the range at any given time. They used radio frequency identification (RFID) tags to monitor hen movement in and out of the pop holes but only Gebhardt-Henrich *et al*. (2014) was able to explore whether the hens had actually continued into the range or not.

Rechards *et al*. (2011) reported that approximately 80% of laying hens used the pop holes frequently and the reports of the current study showed that greater proportion of the ranging hens were found in the region around the pop holes. The presence of a high number of hens in this area has the potential to limit the movement of the motivated hens in and out of the shed thereby resulting in poor range use.

The pop holes were provided along the entire length of the sheds and either located on one or both sides of the sheds to allow the hens sole and direct access in and out of the range. No effect of pop hole location on the use of range was detected but pop hole location interacted with zone, and showed that the hens housed in both single and double sided sheds showed variations in the use of the three outdoor zones but not within. The hens concentrated around the shed in both cases i.e. hen density decreased towards the end of the range Scientists have investigated the effect of pop hole availability (Sherwin *et al*. 2013; Gilani *et al*. 2014) and dimensions (Harlander-Matauschek *et al*. 2006) on the use of range but no study has explored the impact of pop hole location on the use of range in laying hens. The use of range in flocks with the double-sided pop holes was expected to be greater than their single-sided counterparts based on the fact that the hens in double-sided pop sheds had access to the range from both sides of the shed resulting in shorter walking distance to the range compared to their single-sided counterparts. Gilani *et al*. (2014) reported that increased pop hole availability (cm/bird) resulted in an increase in the percentage of range use in 33 flocks of commercial free-range laying hens and concluded that ranging improved during the rearing and laying periods with increased availability of pop holes to the hens. Sherwin *et al*. (2013) investigated the prevalence of nematode infection and faecal counts in free-range laying hens in relation to housing and husbandry practices and reported that the percentage of hens using the range significantly correlated with the number of pop holes, indicating that more hens used the range when there were more pop holes exits available to them.

Effect of time of the day on the use of range

The results showed that time of the day had a significant influence on the use of different parts of the range with more hens found to range in the morning than in the afternoon periods. Generally, the hens were found to use the apron most, followed by the enriched and outer range zones respectively at all times of the day and in addition to this, there was daily variation (range use at different times of the day) in the hen numbers within the apron and outer range zones but not on the enriched area of the range, indicating that daily outdoor use fluctuated in the apron and outer range zones but was found to be stable in the enriched zone. The results of the interaction further showed that there was a similar daily pattern of the use of apron and outer range zones by the hens, although this pattern was more pronounced in the apron compared to the outer range area. The use of apron zone peaked in the morning (i.e. 10am) and decreased through the day, whereas hen number in the outer range was similar between 10am and 1pm, but dropped after 1pm. Many studies have reported daily variations in the use of range by laying hens with some reports that range use peaked use in the morning (e.g. Mahboub *et al*. 2004; Hegelund *et al.* 2005; Nagle and Glatz, 2012), afternoon (e.g. Richards *et al*. 2011) and evening (e.g. Bubier and Bradshaw, 1998). There is a significant amount of evidence that range use peaks mostly after opening the pop holes in the morning (Mahboub *et al*. 2004; Hegelund *et al.* 2005; Nagle and Glatz, 2012) and this was in line with the suggestions from most farmers encountered during the current study.

There are indications that range use may have been associated with the daily changes in the activity pattern of the hens (e.g. Carmichael *et al*. 1999; Abouelezz *et al*. 2014). Carmichael *et al*. (1999) reported that time of the day had a significant effect on the occurrence locomotory behaviour in laying hens with greater movements recorded in the morning than in the afternoon (8.6% in the morning vs 8.0% in the afternoon). Abouelezz *et al*. (2014) reported a similar trend in the activities of laying hens with greater foraging, exploration, roaming and primping found to occur most in the early hours of the morning. Their reports suggested that the decrease in range use reported in later in the day, in the current study may have been a result of the reduced movement of the hens through the day especially in the larger flocks. Nagle and Glatz (2012) reported that the percentage of laying hens found in the range varied through the day and depended on the type of resources available to the hens. They reported that the hens that had no outdoor enrichment did not show any difference in the use of range during the day (45%), but there were more hens outdoors in the morning (55%) than in the afternoon (30%) when forage was provided for the birds. They also found that provision of shade cloths outdoors attracted more hens to the range in the morning than in the afternoon. However, they did not find similar time effect on range use when shelterbelts were provided for the hens, where increased use of range was seen in the afternoon compared to the morning period. It could mean that the differences in the daily ranging pattern of the hens reported above (Bubier and Bradshaw, 1998; Mahboub *et al*. 2004; Hegelund *et al.* 2005; Richards *et al*. 2011; Nagle and Glatz, 2012) was influenced by the availability and the nature of enrichment resources provided in the range and future studies can use resource mapping strategy (identification of type, number and location of resources in the range) to determine if resource type would influence daily changes in the number of hens outdoors.

Effect of hen strain on the use of range

The flocks utilized in the current study comprised of Hyline and Lohmann Brown strains of laying hens and the results of the study showed that strain effect was detected within the outdoor zones with the hens of both strains found to use the apron most followed by the enriched and outer range zones respectively. Also, the use of range varied between the two strains in the enriched and outer range areas of the range but not in the apron strip. The Hyline hens found to show greater use of the enriched and outer range zones compared to their Lohmann Brown counterparts. Effects of strain on fear response and pecking tendency (Klein *et al*. 2000; Kjaer, 2000; Odén *et al*. 2002; Albentosa *et al*. 2003; Zeltner and Hirt, 2008b) and use of range (Mahboub *et al.* 2004; Zeltner and Hirt *et al*. 2008a) in laying hens have been studied and with mixed results reported. Mahboub *et al*. (2004) reported that the frequency of visits and proportion of time spent by laying on grassland was influenced by their strain. They compared the frequency and duration of outdoor visits between the Lohmann Selected Leghorn (LSL) and the Lohmann Tradition (LT) hens and found that the LSL hens visited the outside area more frequently but spent less time in the grassland compared to the LT hens. This was supported by the further evidence of greater Tonic Immobility (TI) duration seen in the LSL hens compared to their LT counterparts. These outcomes (that the LSL hens were more fearful than the LT hens) suggested the likelihood that other strains of laying hens may have variations in their fear reactions which can in turn affect their ability to use their outdoor space. Albentosa *et al*. (2003) investigated the differences in the behaviour, fear response and pecking activities of four layer-type hen strains and reported that TI was strongly influenced by strain of the hens, with White Leghorn hens found to show the longest TI duration compared to the Columbian Blacktails, Isa Brown (ISA), and Ixworth (IX) hens. They also reported that a reduction in the fear reactions was associated with an increase in the exploratory behaviour of the hens as they grew older and therefore concluded that strain of the hens had influence on their behaviour and fear reactions. Odén *et al*. (2002) also reported genetic effect of the fearfulness of laying hens with different hybrids found to show significant differences in their degree of fear reactions. They investigated six different hybrids of laying hens housed in 51 flocks kept on 25 farms in Sweden and concluded that white hybrids of laying hens reacted more to the keepers and novel objects than the brown hybrids.

However, Zeltner and Hirt (2008b) reported that although all the hen strains observed in their study showed fear reactions by running back into or in the direction of the shed during a frightening event, there were no differences in the reaction, recovery times and in the use of range between them. They utilized three different genetic strains of laying hens (LSL, ISA brown and ISA black) in their experiment and exposed the hens to a simulated hawk attack and concluded that no hen strain had better attribute than the others in terms of the fear reaction and behaviour in the range.

The hens used in the current study did not have sufficient cover and being that many studies have reported that different strains of laying hens are susceptible to fear (Zeltner and Hirt, 2008b) or may feel vulnerable to predator attacks (e.g.

Collias and Collias, 1967; Grigor, 1993; Weeks and Nicol, 2006) and inclement weather conditions (Keeling *et al*. 1988; Hoekstra *et al*. 1998; Nicol *et al*. 2003; Hegelund *et al*. 2005; Richards *et al*. 2011), it was possible that the Lohmann Brown hens were more fearful than their Hyline counterparts. Also, the number of individuals in the Lohmann Brown hens was generally greater compared to the Hyline hens and being that the current study and other studies (e.g. Bestman and Wagenaar, 2003; Gilani *et al*. 2014) have found that the hens in smaller flocks ranged more than their counterparts in larger flocks, it was possible that flock size had resulted in this difference rather than the strain differences. Another possible explanation for the differences in range use between the two strains could be because the Hyline flocks were visited in warmer months (November to December) whereas the Lohmann Brown hens were observed during the colder months (January to February) and there is evidence that higher temperatures encouraged range use in laying hens (e.g. Hegelund *et al*. 2005; Richards *et al*. 2011). A further study will be beneficial to separate the effect of flock size and strains on the ability of hens to use the range e.g. by using same flock size and more hen strains.

Effect of age on the use of range

The results showed that age of the hens had a positive influence on their ability to use that range, with older hens found to use the range more compared to their younger counterparts. The lack of interaction between age and zone means that the preference of the hens for different outdoor zones was not affected by their age and this suggested that hens of all ages showed similar pattern in the use of the three outdoor zones. Gilani *et al*. (2014) studied the effect of environment on the use of range and found that there was no difference in the range use between flocks with and without access to the range during rearing the percentage of the hens that used the range increased with age during the laying period. They argued that early experience in the range was expected to result in greater use of range but there was no evidence that early range access (during the rearing period) had any effect on the proportion of the flocks found outdoors during the laying period. Their finding is in line with that of the current study where laying hens were studied during lay where age was found to influence outdoor use as range use increased when the hens got older. Age related difference in the behaviour, fear response and pecking tendency of four strain of laying hens has been investigated (Albentosa *et al*. 2003). They aimed to determine if the strain and age of the hens had any influence on their fear responses during behavioural tests e.g. open field, novel object tonic immobility (TI) and loose feather bundle tests administered to the hens between 4 and 13 weeks of their age, followed by a fixed feather test at 26 weeks of age. They reported that age had a significant effect on the behaviour of the hens, with exploratory behaviour found to increase as the hens got older. It could be that the older hens had become more familiar with the range as they got older thus the greater turnout of the older hens or probably because the older hens were less likely to show fear response in the range (e.g. Jones, 1977; Grigor *et al*. 1995a; 1995b).

However, Hegelund *et al*. (2005) reported that age had a negative effect on the ranging ability of laying hens after housing, with greater percentage of younger hens found to leave the shed compared to the older flocks with reduced turnout.

They described their result as unexpected and suggested that there may have been an initial increase in the use of range after housing (when the hens became familiar with the outdoor run), but the pattern did not last through the entire period of production. The duration of the current study was not as long as that of Hegelund *et al*. (2005), and had less number of flocks (6 vs 37 free-range laying hens flocks) made up of relatively larger number of individuals in the flocks (4000 to 24000 vs 513 to 6000 hens). It was likely that the differences in the study variables e.g. study length and flock size had resulted in the different patterns of range use as seen in the two studies.

Effect of flock size on the use of range

The current study showed that the number of hens in the range decreased in larger flocks whereas range use was found to increase in smaller flocks. The interaction between flock size and outdoor zone suggested the hens in different flocks showed variations in their numbers/quadrat within and between the three outdoor zones e.g. there were greater number of hens in the apron, followed by the enriched and outer range zone in all group sizes. Also, there was a similar pattern in the use of all the outdoor zones by the hens, with the use of apron, enriched and outer range zones found to be greatest in smaller flocks compared to their larger counterparts. Inverse relationships have been found to exist between flock size and range use in free-range laying hens (e.g. Bestman and Wagenaar, 2003; Gilani *et al*. 2014) and this can explain why larger proportion of the hens especially in large flocks did not use the range in the current study. Although these studies did not provide additional details on the use of different outdoor locations, they highlighted the impact of group size on the ability of the hens to use the range and based on the evidence seen in the current study, the impact of increase flock size on range use was not only found in the overall outdoor use but was also detected in each of the three outdoor areas.

Pettersson *et al*. (2016) argued that the differences in the number of individuals in ranging flocks may not be sufficient to explain their variation in the use of range, unless it is considered alongside the stocking densities. Carmichael *et al*. (1999) studied 3000 laying hens housed in 10 groups of 300 hens at different stocking densities and found that hen movement was also inhibited in the group kept at the higher density (19.0 birds/m^2) compared to the lower density group (9.9 birds/m^2 hens). Their work highlighted the possible impact of stocking density on the ability of the hens to use the range. The RSPCA and the EU commission (1999) outlined the minimum stocking density for free-range laying hens in the shed (≤ 9 hens/m^2 or 0.11m^2/hen) and outdoors (≤ 2,500 hens/hectare or 4m^2/hen at any one time). The laying flocks used in the current study were kept at the similar stocking densities and based on this, stocking density was ruled out as a potential influencing factor in the use of range. Bestman and Wagenaar (2003) studied 63 organic flocks of laying hens on 26 farms in Netherlands, and found that flock size had a significant effect on the proportion of the flocks found in the range. They reported greater outdoor use in smaller flocks compared to the larger groups and their finding is in agreement with the work of Gilani *et al*. (2014) who also reported an increase in range in smaller flocks and also in flocks with reduced stocking density. Increased flock size has been associated with reduced range use in larger flocks (Bestman and Wagenaar, 2003; Gilani *et al*. 2014), thus a greater proportion of hens will stay in the shed, thereby leading to reduced roaming space and increased indoor stocking density that has been found to be associated with decreased movement and increased standing activities in laying hens (Appleby *et al*. 1980, Appleby *et al*. 1989; Carmichael *et al.* 1999). Since higher stocking density had been found to restrict movement and also lead to increased standing behaviour in laying hens, it was likely that the reduced range use reported in the current study may be a resulted of the similar limiting effect of the higher indoor stocking density associated with poor range use of the hens in larger flocks.

Gilani *et al*. (2014) studied a total of 33 flocks of laying hens, reared with or without access to the range at 8, 16 and 35 weeks of age and concluded that ranging was improved by reducing the flock size and stocking density inside the hen house. Based on this, it was likely that more hens observed in the current study will use the range if the number of individuals in the flocks is reduced.

Also, being that the RSPCA (2013) and the EU's (1999/74/EC) minimum space requirements were met by the study flocks, the implication was that the larger flocks had larger sheds and greater outdoor space compared to the smaller flocks but at similar stocking densities. The differences in the house and range sizes between larger and smaller flocks could mean that the fewer hens that ranged in larger sheds needed to travel greater distances within the shed to access the range or may be discouraged by the presence of other hens or other physical barriers that they will encounter when leaving the shed.

Nearest neighbour distance of the hens in the range

The NND of the hens was influenced by their location (zone) in the range and with the hens in the outer range found to show the greatest NND than their counterparts closer to the shed, suggesting that the space between individual hens rose as the distance from the shed increased. Social factors e.g. aggressive dominance hierarchy (Keeling and Duncan, 1989b), presence of other individuals (Kummer, 1971), behaviour and strain (Keeling and Duncan, 1991, Keeling, 1994) have been reported to influence the spatial organization of individuals and with the evidence that laying hens do not use all the space available to them (Keeling and Duncan, 1989a; Newberry and Hall, 1990; Arnould and Faure, 2003; Nicol, 2007) with skewed distribution of birds in the range being likely. Differences in the type of resources e.g. feeders, drinkers, nest boxes (Mankovich and Banks, 1982), available in different locations of the bird habitat has been suggested to be one of the precursors of such skewed distribution. The results of the current study showed that most of the hens in the range were found in the area closest to the shed (e.g. Keeling *et al*. 1988; Nicol *et al*. 2003; Hegelund *et al*. 2005, 2006; Nagle and Glatz, 2012) and they may have resulted in higher local stocking density in this area that was expected to result in a reduced NND. The analysis of the relationship between number of hens and the NND of the hens in the range contradicted this expectation as it showed that the number of hens in the apron was less likely to influence their NND. However, this result may not serve as the best predictor of the relationship between hen number and NND as the approaches used in sampling hen number and NND of the hens in the range was different. The hen number was obtained within the 11 quadrats spread out across the three outdoor zones whereas the NND measurements was not carried out in the quadrats. In addition to this, the quadrat and NND measures were carried out at different times of the day, and the fact that the number of hens in the range varied throughout the day made it more difficult to draw conclusions on the presence or absence of the relationships.

The evidence from a recent study have shown that laying hens mostly clustered around important resources (Collins *et al*. 2011), suggesting that clustering is caused by resource use rather than social cohesion. The results of the correlation analysis between hen number and the NND of the hens showed that an overall increase in the number of hens in the range resulted in a decrease in their NND. The results further showed that there was a significant positive relationship between hen number and NND in the outer range zone but not in the apron and enriched areas. It was expected that the increase in the number of hens outdoors would result in decrease in the NND in all the outdoor zones but the hens in the outer range increased the distance between themselves as the number of individuals increased. There are indications that the activity states of the hens in the outer range may be associated with the distance between them as reported by Keeling and Duncan (1991). Their study provided an evidence that the behaviour of laying hens had a significant impact on the space they keep between themselves with individuals found to be furthest apart when walking but stayed closer during pecking, standing and preening activities. They studied two strains of laying hens in a large outdoor enclosure (110 x 80 m) in two experiments and concluded that the distances between the hens in both experiments varied with their activity states. Also, Keeling (1994) reported a similar association between behaviour and inter-bird distances of laying hens in a study that explored the effects of spatial restriction on the frequencies of different behavioural patterns performed by laying hens. Hens were kept in groups of three, in four different sized letter pens to give different space allowances to the birds. The distance between the birds in each group was measured when all the birds were seen performing the same activity and the hens were found to show greatest inter-bird distance when foraging and walking and least inter-bird distance when standing, ground pecking and preening. The hens in the current study were more likely to engage in walking and foraging activities in the outer range area and with resting behaviour being the most dominant activities in the apron zone, it was possible that the hens in the outer range had the moved greater distance from one another hence the greater NND in this zone compared to the apron bound hens with the least NND. The findings of the current study and other scientific evidence (Keeling and Duncan, 1991, Keeling, 1994) have further suggested that the distances between individual hens in the range can be predicted based on their activity states.

Effect of pop hole location on the NND of the hens

The results showed that the NND of the hens in different range zones was influenced by the location of the pop holes around the sheds with the hens housed in double-sided sheds found to show greater NND than their counterparts in single sided sheds. This increased NND was detected in the apron, enriched and outer range zones and with the values found to peak in the outer range zone, followed by the enriched and apron areas respectively. This showed that the NND of the hens generally decreased towards the shed. Recent studies have investigated the effect of pop hole dimension and availability on the ranging behaviour of laying hens (Harlander-Matauschek *et al*. 2006; Sherwin *et al*. 2013; Gilani *et al*. 2014) but so far, no work has published on the effect of the location of pop holes on either one of two sides of hen house on their ability laying hens to use that range. The evidence from the studied on the effect of pop hole availability (Sherwin *et al*. 2013; Gilani *et al*. 2014) and dimensions (Harlander-Matauschek *et al*. 2006) showed that laying hens use the range more when they had access to increased number of pop holes but there was no evidence that larger sized pop holes encouraged range use. In the current study, the sheds with pop holes on both sides appeared to have offered the hens greater opportunities to maximize personal space but this effect was not clearly understood. This is because the size of the shed and the number/size of the pop holes were subject to the EU Directive (1999) and depended on the number of hens in the flocks. However, a more objective study is required to determine if the location of pop holes on either one or two sides of the shed had any effect on the NND of the hens in the range or outcome of the interaction between other variables.

Effect of age on the NND of the hens

The age of the hens in the different areas of the range had a significant effect on their NND with greater distance found in older hens compared to their younger counterparts with reduced NND. The NND was greatest in the outer range, followed by the enriched and apron zones respectively i.e. the NND of the hens decreased towards the shed irrespective of the hen age. NND was more likely to increase with age, as the older hens seemed to keep greater distance away between them when compared to the younger flocks. Evidence have shown that range use increased with familiarity (incresead age) in chickens (Jones, 1977; Grigor *et al*. 1995a; Zeltner and Hirt, 2003; Hegelund *et al*. 2005; Gilani *et al*. 2014) and that the fear response in birds decreased when they become familiar with their environment (Grigor, 1993). The results of the current study further indicated that the hens in the older flocks showed signs of increased familiarization of their surroundings through the increased use of the range alongside the age related increase the foraging behaviour in the outer range. Since the familiarization of outdoor range increased with age and the associated decrease in fearfulness, the older hens appeared to demonstrate that they did not need to stay close to one another in the range (especially in the outer range). Also, the greater number of hens in the range reported in older flocks (Zeltner and Hirt, 2003; Hegelund *et al*. 2005; Gilani *et al*. 2014) may have been associated with increased competition for the foraging resources which may have encouraged the hens to keep greater distances from one another to reduce conflicts associated with resource competition. This is supported by the Keeling's (1995) argument on the value of personal space as a means of assessing limited resources by animals e.g. the older hens in the current study may keep greater distance from other hens so that they can exploit these resources in isolation.

Feather condition of the hens in the range

The feather score data collected during this study showed that the feather condition of the hens depended on the part of the body with indications that the feathers from the neck region had the poorest condition (with greatest feather loss). The part of the hens with the best feather condition was the side, followed by the back and chest feathers respectively. Scientists have suggested that feather pecking do not only lead to feather damage but also injuries and potentially death of birds (Hughes and Duncan, 1972; Allen and Perry, 1975, Appleby and Hughes, 1991) thus, factors found to encourage feather pecking are likely to result in greater feather damages on the affected body part. Increased feather damages have also been associated with resource use e.g. loss of neck feathers resulting from abrasion of the neck of hens on the feed troughs during feeding (Bilcik and Keeling, 1999), which can also explain the poor feather condition of the neck feathers reported in the current study. The outcome of the studies of the feather condition of different body parts of laying hens showed variations in their preferences for feathers from different body parts (Allen and Perry, 1975; Mahboub, 2004). While Allen and Perry (1975) found that the hens directed more feather pecks to the back and wing feathers, Mahboub (2004) reported that greater feather pecks were recorded in the head and neck region of the hens. The differences in outcomes of these two studies may be accounted for by the differences in the husbandry practices under which the chickens were kept. Mahboub (2004) investigated the feather pecking and body condition of two genotypes of laying hens housed in different free-range systems whereas Allen and Perry (1975) studied the hens in caged conditions. The report of Mahboub (2004) supports the findings of the current study and this could mean that the hens observed in the current study may have directed more pecks to the neck region to secure feeding spots thereby causing greater feather loss, thus the poorer feather condition in the neck region. However, the findings of the current study did not agree with the work of Bright *et al*. (2006) who studied the plumage condition of laying hens in commercial conditions. They found that majority of the damage reported during their study was found in the rump region, followed by the tail, neck, back and wing feathers and attributed their findings to greater feather pecking activities directed to the back/rump region as seen in other studies (e.g. Tauson *et al*. 1984; Bilcik and Keeling, 1999).

A potential source of variation between the outcome of the current study and other published studies is the feather scoring method itself (e.g. Hughes and Duncan, 1972; Allen and Perry, 1975; Tauson et al. 1984; Gunnarsson *et al*. 1995; Bilcik and Keeling, 1999; Bestman and Wagenaar, 2003; Tauson *et al*. 1984; 2005; Bright *et al*. 2006). In the current study, a 6-point scale was used to score the degree of damage to the feathers, by assigning single number to feathers from 4 body parts of the hens. In other published studies, scientists assessed feather condition of chickens by either using similar approach described in the current study (e.g. Tauson *et al*. 1984; 2005) or by assessing the whole body of the hens (e.g. Hughes and Duncan, 1972) using different scoring scales e.g. 9-point, 5-point, 4-point and 3-point scales (Hughes and Duncan, 1972; Allen and Perry, 1975; Gunnarsson *et al*. 1995; Bestman and Wagenaar, 2003; Tauson *et al*. 1984; 2005; Bright *et al*. 2006). The use of fewer scale points (e.g. 3-point) is considered to be more beneficial than the larger scale points (e.g. 9-point) as they cover wider range of feather conditions and may be more consistent between scorers (Bright *et al*. 2006). A validation study of the non-intrusive feather soring technique utilized in the current study has been carried out and it suggested to be a reliable estimate of flock feather damage although capture and handling method would provide a more reliable estimate of feather damage in flocks with large individual variations (e.g. Bright *et al*. 2006). While capture and handling technique allows close and detailed inspection of the birds, it was argued to be a difficult and time consuming task, with potential production and welfare implications to the birds (Bright *et al*. 2006).

Effect of outdoor location on the feather condition of the hens

The results of feather score analysis showed that the hens in the outer range zone had the overall best feathers whereas the hens found in the apron had the worst feathers and this effect was similar for all ages, flock sizes, location of pop holes and strains. The hens in the enriched zone had better feathers than their counterparts in the apron zone but worse than the hens in the outer range zone. The local stocking density of the hens varied between the three outdoor zones and was greatest in the apron zone where hens had poorest feather cover. Bestman *et al*. (2009) found that high stocking density was associated with increased injurious feather pecking in organic laying flocks, probably caused by aggression created by competition (Hughes *et al*. 1997). They studied the feather condition of hens in 28 commercial organic flocks (split into 51 flocks) at young and adult age and concluded that keeping higher number of pullets per square metre during rearing was a risk factor for feather damages in laying hens. Foraging behaviour has been found to share an inverse relationship with feather pecking (Huber-Eicher and Wechsler 1997) and feather damages also reported to be linked to insufficient foraging opportunities (Aerni *et al*. 2000) in laying hens. They reported that increased foraging activities and reduced feather damages was found in the hens with access to foraging materials. In the current study, greater foraging activities was recorded in the outer range zone and the feathers of the hens in this zone had the overall best condition. The reports of (Huber-Eicher and Wechsler 1997; Aerni *et al*. 2000) suggested is in line with that of the current study where the hens appeared to have substituted feather pecking with foraging activities in the outer range zone. There are indications that the greater foraging activities in the outer range zone had a beneficial effect on the plumage condition of the hens.

It was also possible that the hens in the outer range zone had greater chances of avoiding aggression or being pecked at due to the greater NND they had. Greater personal space appeared to have created more roaming space and less competition for substrates. However, it was not clear whether the hens found in different outdoor locations used such areas regularly and a further study will be beneficial to determine whether individual hens prefer to use specific outdoor areas and the potential benefits e.g. improved feather condition, of their choices.

Effect of strain on the feather condition of the hens

Two strains of laying hens were used in this study and based on the results of the analysis, the feather condition of the neck, chest and back regions of the hens was significantly influenced by strain of the hens with the Hyline hens found to have the least feather scores (better feather) compared to their Lohmann Brwon counterparts that had greater feather damages. This effect of strain on the feather condition of the hens reported in the current study suggested that this is linked to the genetic makeup of the hens (e.g. Richter, 1954). Feather condition of the side feathers did not vary between the two strains of hens and this may be because of the minimal damages recorded in the side feathers of the hens. Studies have found that feather pecking result in feather damages (Bilcik and Keeling, 1999; Kjaer and Søresen, 2002; Bright *et al*. 2011) and based on this evidence, it was possible that the feather condition of different hen strains would vary. The effect of genotype on feather pecking and feather damages in laying hens have been explored (Hughes and Duncan, 1972; Kjaer and Søresen, 1997; 2002; Klein *et al*. 2000; Albentosa *et al*. 2003; Mahboub *et al*. 2004; Mohammed and Said, 2016) and it was suggested that feather pecking behaviour have genetic basis and can be passed from parent to their young as a hereditary factor (Richter, 1954). Studies have also shown that feather pecking can be selected for or against (Keeling and Wilhelmson, 1997). Klein *et al*. (2000) tested whether genetic differences in foraging behaviour was paralleled by hybrid-specific differences in feather pecking in laying hens. They carried out two experiments and the second experiment focused on how foraging behaviour of two strains of laying hen chicks (LSL and Dekalb) differed when their housing condition changed and its effect on feather pecking development. They found that both hybrids developed feather pecking behaviour but the LSL chicks showed significantly higher rate of feather pecking than the Deklab chicks. Mohammed and Said (2016) studied the behaviour of two strains of laying hens (Lohmann breed and LSL) housed in two different types of enriched cages (Salmet and Dutchman systems) and found breed effect on feather pecking behaviour with Lohmann brown hens found to engage in greater feather pecking activities than the LSL breed. They suggested that the selection a good strain and cage system for keeping laying hens is important in the control of feather pecking behaviour. Kjaer and Søresen (2002) investigated the effect of genotype, dietary level of methionine and cysteine, light intensity during rearing and age at first access to the range on feather pecking and cannibalism in free-range laying hens. They reported large differences in plumage and skin damages between genotypes (ISA brown, New Hampshire, White Leghorn and cross between New Hampshire and White Leghorn) which was associated with feather pecking. The differences in the feather pecking activities and feather damages of different hen strains in the studies discussed above supported the findings of the current study and suggested that there may have been strain differences in the feather pecking behaviours of the Hyline and Lohmann Brown hens (e.g. Kjaer and Søresen, 2002). There are also indications that the influence of strain on use of range (e.g. Mahboub *et al*. 2004) was associated with the variations in the feather pecking activities of the hens (e.g. Jones, 1997) where greater range use was recorded in the Lohmann Brown hens compared to their Hyline counterparts.

Effect of age on the feather condition of the hens

The results showed that feather condition of all the observed body parts of the hens in all parts of the range was influenced by their age although this effect was in an unexpected direction. It was expected that the younger hens would have better feathers compared to their older counterparts as reported in other studies (e.g. Gilani *et al*. 2013; Petek *et al.* 2015), but the reverse was the case, as the older hens were found to have better feathers than their younger counterparts. Petek *et al.* (2015) found that age had a significant effect on the plumage quality, but not on the pecking behaviour of laying hens housed in similar pens with access into the range at 18, 20 and 22 weeks of age. They concluded that the total feather damage increased significantly with age and that allowing laying hens access into the range at earlier age had resulted in reduced feather pecking, thus improved the feather condition of the hens at later age. However, Gilani *et al*. (2013) studied 34 rearing flocks of laying hens at the beginning, middle, end of rearing period and during lay period. They used the information gathered from the rearing environment to create models that predicted feather pecking and feather damages in the hens. They reported that feather pecking and feather damages occurred during the rearing and lay periods, with the rate of severe feather pecking found to increase with age (0.4 pecks/bird/h for rearing and 1.9 pecks/bird/h for lay period). They also reported that the percentage of the flock with missing feathers increased with age (12% at rearing, then 49% at lay). Nicol *et al*. (1999) studied the effects of increased stocking density on the feather pecking and aggression levels of laying hens and found that both mild and severe feather pecking increased significantly with age of hens. Their report suggests that the increase in feather damages reported in other studies may be associated with the increase in the feather pecking activities found to increase as the hens got older. LaBrash and Scheideler (2005) studied two farms of laying hens between 21 and 113 weeks of age to determine if age (partitioned into production cycles) had a significant influence on the feather condition of the hens. They plotted feather scores against time (age of production) and found that the overall feather score increased (increased feather damages) over time in all the production cycles, in line with the variations in feather quality during egg production. Their results further showed that the hen feathers deteriorated in two production cycles but improved with moulting (the process of shedding off and renewing feather), although not to the optimal condition observed in the earlier weeks of egg production. LaBrash and Scheideler (2005) reported that the hens had smooth and complete feathers between 21 and 33 weeks of age which differs from the work of Bilcik and Keeling (1999), which reported that feather damages occurred at earlier age in the hens (18 to 32 weeks of age). The findings of Bilcik and Keeling (1999) showed that the hens had little or no feather damages at early lay (18 weeks) but reported rapid changes in their feathers from this age onwards, implying that feather losses increased with age.

The studies discussed above suggest that the differences in the feather condition of hens of different ages may mean that greater feather damages had occurred in the younger hens at the time of the study. It was also possible that the unexpected improved feather condition reported in the current study may be a result of moulting activities and may explain why older hens had better feathers compared to their younger counterparts.

While other studies had reported that aging was generally associated with increased feather pecking behaviour and feather damages in laying hens, they were presented as cross-sectional (e.g. LaBrash and Scheideler, 2005) or prospective (e.g. Bilcik and Keeling, 1999; Nicol *et al*. 1999; Gilani *et al*. 2013; Petek *et al.* 2015) studies, which determined how much details that was gathered in such studies. In cross-sectional studies, the prevalence of feather damage in laying hens is determined at a given point in time (Mann, 2012), with no interest on how it developed over time. As cross-sectional studies do not require a follow up, it is a relatively quick and cheap method of carrying out an observational study. However, as the flocks of laying hens studied by LaBrash and Scheideler (2005) was not studied over a period of time, there are limited details collected on the development of feather damage during the production cycles of each of the studied flocks. Prospective studies on the other hand follow the flocks of laying hens over a period of time e.g. in the work of Bilcik and Keeling (1999), the changes in the feather conditions in relation to feather pecking and aggressive behaviour of laying hens was studied between 18 and 33 weeks of age. Though this method of observation is associated with prolonged length of time and increased costs, it measures events in chronological order and often includes greater details, especially on how the changes in the feather conditions had occurred over time (e.g. Bilcik and Keeling, 1999; Nicol *et al*. 1999).

Behaviour of the hens in the range

The evidence from the current study showed that the hens were more likely to engage in foraging behaviour, followed by resting, locomotory comfort and aggressive behaviours respectively in the range. The proportion of foraging, resting and locomotory behaviours recorded in the range was influenced by the location of the hens in the range with the hens found in apron zone more likely to engage in resting behaviour compared to their counterparts in the enriched and outer range areas. Foraging and locomotory behaviours dominated the outer range zone but decreased towards the shed with least proportion of foraging behaviour recorded in the apron zone whereas locomotion occurred least in the enriched zone. The evidence of the measures of the range showed that the NND of the hens was greatest in the outer range and decreased towards the shed and there are possibilities that the behaviour of the observed hens was influenced by the proximity of other hens in the range. Dawkins and Hardie (1989) measured the amount of space required by hens to perform different behaviours using videotapes and reported that the hens required 540 to 1006 cm^2 when turning compared to the 653 to 1118 cm^2 used during wing stretching, 860 to 1980 cm^2 during wing flapping, 676 to 1604 cm^2 when feather ruffling, 814 to 1270 cm^2 when preening and 540 to 1005 cm^2 during ground scratching activities. Their findings showed that laying hens have different space requirements when performing different behaviours and this could be the reason behind the differences in the proportion of foraging behaviour, resting and locomotory behaviours recorded between the three outdoor locations. Nicol (1986) carried out similar behavioural study on a medium sized laying hybrid, housed in battery cages of different heights and found that providing greater space for the hens resulted in increased head scratching, body shaking and feather raising activities but cage pecking activities decreased in such conditions. It was concluded that the spatial restriction of laying hens in the cages resulted in increased cost of performing certain behaviours e.g. comfort behaviours and may discourage the hens from performing such important behaviours. Rhim (2014) found that the behaviour of commercial laying hens was affected by the amount of floor space available to them, with the hens in small and medium cages found to perform greater standing, dozing and sleeping behaviours compared to the increased walking activity recorded in the larger cages.

There are possible effects of enrichment resources on the behaviour of the hens in the range. The outdoor zones marked in the current study were distinguishable not only by their relative distance from the shed but also on the type of enrichment resources found in them and based on this, there are chances that the differences in the behaviour of the hens between the zones was influenced by these resources. Many studies have reported that environmental resources have pronounced influence on the behaviour of laying hens e.g. increased perching activities (90-94% of hens in the flocks) at nights when perches are provided (Appleby *et al*. 1993; Olsson and Keeling, 2000) and increased resting and preening behaviours when artificial vertical panels are provided for the hens (Newberry and Shackleton, 1997). Olsson and Keeling (2000) investigated the effect of perch availability on the perching behaviour of hens with thwarted access to perches and reported that the hens increased their movements and perched less when perches were not accessible to them. Their findings did not only report a decline in perching activities when perches were not provided for the hens but also that there was a shift in their activity pattern (increased movement) as a possible show of frustration or a site seeking activity to compensate for the reduced perching opportunities (Olsson and Keeling, 2000). Newberry *et al*. (1997) examined the use of cover in two strains of laying hens (Brown Leghorn and Commercial strain) kept indoors and found that the hens showed greater resting and preening behaviours in areas with cover compared to uncovered quadrants. They concluded that the provided cover had a significant impact on the behaviour and habitat use in laying hens. The reports of the studies presented above (Newberry *et al*. 1997; Appleby *et al*. 1993; Olsson and Keeling, 2000) suggested that the environment resources have the potential to influence the behaviour of laying hens and there are chances that the behaviour of the hens in the current study depended on the amount of space and the type of resource they encountered in the range. A typical example is the increased proportion of foraging behaviour recorded in the outer range with ample grasses.

Effect of age on the on the behaviour of the hens

Age of the hens used in the current study interacted with zone in the proportions of feeding/foraging and locomotory behaviours and this indicated that foraging behaviour differed between age groups only in the outer range zone. Locomotion also differed between the age groups of hens in the enriched and outer range areas. While feeding/foraging behaviour was found to increase with age in the outer range zone, locomotory behaviour increased in the enriched zone and decreased in the outer range area as the hens got older. Resource availability appeared to have influenced the changes in the behaviour of the hens of different ages found in the different parts of the range e.g. older hens performed more foraging behaviour in the outer range probably because they were braver and less fearful to explore and forage in this area (Albentosa *et al*. 2003; Gilani *et al*. 2014) with associated reduction in their movement during foraging activities. It was earlier reported in the current study that the older hens used the range more and this may mean that they had greater chances of performing foraging behaviour in the range as they got older and became familiar with their environment (e.g. Grigor *et al*. 1995a). The result of the current study did not agree with the work of Petek *et al*. (2015) but is in line with the reports of Bilcik and Keeling (1999) and Nicol *et al*.

(1999) who found that age was an influencing factor on the behaviour of laying hens. Although there are a number of studies that investigated the effect of age on the behaviour of laying hens, they focused mainly on feather pecking and aggressive behaviours and not the general behaviour output of the hens (e.g. Bilcik and Keeling, 1999; Nicol *et al*. 1999; Petek *et al*. 2015). Effect of age at first access to the range on the feather pecking and the feather condition of 16 week old pullets housed in an experimental free-range house was studied by Petek *et al*. (2015). They measured the pecking behaviour and plumage quality of the hens between 24 to 48 weeks of age and found that pecking behaviour was not affected by age of the hens, although feather damage was found to increase with age. Bilcik and Keeling (1999) explored the changes in the feather condition of laying hens in relation to feather pecking and aggressive behaviours and found that the number of aggressive feather pecks (27 and 32 weeks) increased with age. They assessed the relationship between feather damage and the behaviour of the hens using multiple linear regression approach and found that aggressive feather pecking was associated with reduced body weight and increased feather damages in the hens. Nicol *et al*. (1999) investigated the effects of increased stocking density, mediated by increased flock size on feather pecking and aggressive behaviour of laying hens between 14 to 30 weeks of age and reported mixed outcomes. They found that while mild feather pecking increased with the age of the hens, severe feather pecking was infrequent especially in the smaller flocks and lower stocking densities. The findings of some of the above studies (Bilcik and Keeling, 1999; Nicol *et al*. 1999) broadly revealed that age had the potential to influence the behaviour of laying hens but the current study did not detect a general effect of age on the behaviour of the hens rather age related changed in the foraging and locomotory behaviour of the hens was found in the enriched and outer range zones. Although the behaviours measured in the current study are different from the feather pecking behaviour measured in other studies, age effect may be an indication of the changes in the activity level of the hens as they age.

Effect of pop hole location on the behaviour of the hens

The behaviour of the hens in different parts of the range was affected by the location of the pop holes on the sides of the shed and this means that the hens in single and double sided sheds showed similar behavioural patterns in the range. The interaction between zone and pop hole location suggested that proportion of resting and feeding/foraging behaviours varied between the exit types. Generally, resting behaviour was recorded most in the apron followed by the enriched and outer range zones although the variation between the single and double exit types occurred only in the enriched area but not in the apron and outer range zones. Also, the proportion of feeding/foraging behaviour seen in the hens housed in both types of exits also differed between the apron, enriched and outer range zones but not within them. The variations in the proportion of the behaviours between and within zones are thought to be largely influenced by the resources found in these areas. The use of pop holes by free-range laying hens (e.g. Richards *et al*. 2011; 2012) as well as the effect of pop hole availability (e.g. Sherwin *et al*. 2013; Gilani *et al*. 2014) and pop hole dimensions (Harlander-Matauschek *et al*. 2006) on the use of range by laying hens have been reported, but no study has been carried out on the impact of pop hole location (either on single or both sides of the shed) on the behaviour of free-range laying hens. It was not clear why hens with double sided pop holes performed more resting behaviour than their single exit counterparts but there are chances that the enriched area of the double sided flocks offered greater resting opportunities to the hens compared to the single exits.

Effect of strain on the behaviour of the hens

The strain of the hens was found to influence the proportion of resting and foraging behaviours but not locomotion, comfort and aggressive behaviours of the hens in the range. The interaction between zone and strain suggested that the proportion of resting and feeding/foraging behaviours performed by the Hyline and Lohmann Brown hens varied between the three outdoor zones but not within them except the proportion of feeding/foraging behaviour that varied between the two strains in the outer range zone. The proportion of resting behaviour was greater in the apron zone, followed by its decline towards the end of the range, compared to feeding/foraging behaviour that dominated the outer range but decreased towards the shed in the two strains. The Lohman brown hens were more likely to perform feeding/foraging behaviour in the outer range area compared to the Hyline hens, but no variations in the feeding/foraging behaviour was detected in other parts of the range. It was not clear why the Lohmann Brown hens performed more foraging behaviour than the Hyline hens in the outer range area but published evidence suggested that strain of laying hens has a substantial effect their behaviour (e.g. Newberry *et al*. 1997; Hocking *et al*. 2001; Odén *et al.* 2002; Albentosa *et al*. 2003). These studies did not provide any evidence on the effects of outdoor locations on the behaviour of the strains of hens studied but they certainly showed that the genetic make-up of hens have the potential to influence their activities. Odén *et al.* (2002) explored the behaviour of six laying hen hybrids (ISA Brown, Hisex Brown, LSL White, LSL Brown, Shaver White, and Dekalb White) kept in two types of aviary systems (Oli and Vencomatic) as part of a testing programme by the Swedish government to evaluate new laying hen housing systems. They found that strain had no effect on the occurrence of aggressive behaviour but greater feather pecking activities was recorded in brown hybrids compared to their white counterparts. Also, the white hybrid hens were found to show greater fear responses to novel objects and the keepers, suggesting that behaviours varied from one breed to another. Newberry *et al*. (1997) reported that the strains (Brown Leghorn and Commercial) of hens utilized in their study reported that a greater proportion of Brown Leghorn hens was found to engage in resting and preening behaviours compared to their commercial counterparts. Hocking *et al*. (2001) studied the age related differences in fear, sociality and pecking behaviour of two commercial lines of laying hens (Tetra and ISA Brown) reared from hatch. They carried out behavioural tests between 0 to 14, 12 to 21 and 29 to 31 weeks of age and reported that the strain of the hens influenced some of their behaviour (gentle pecks and preening) but not others (resting, foraging, pecking at feather bunch) and concluded that these behaviours were stable independent traits. Albentosa *et al*. (2003) also studied the effect of strain and age on the behaviour, fear response and pecking tendency of laying hens housed in 6 identical rooms of the same building. They utilized four layer strains (White Leghorns, Ixworths, Columbian Blacktails, and ISA Brown) in novel object, open field, loose feather, tonic immobility (TI) and fixed feather tests, to determine if the results from the behavioural tests were strain specific or not. They found that the white Leghorn hens had longer TI durations than the other strains but showed less fixed feather pecking than the ISA Brown and Columbian Blacktail strains. The studies presented above showed that some behaviours were influenced by the hen strain while others did not vary from one strain to another and this mixed result may be accounted for by the differences in the methods used in measuring the behavioural responses of the hens (e.g. direct observations, video recording, tonic immobility and novel object tests).

Conclusions

The evidence presented above showed that fewer than expected proportion of the hens used the range and that the hens in the range did not use all the space available to them, especially the distant areas of the range. The hens were mostly found near the shed, where they rested at close distances. The chances of finding the hens in any given outdoor location decreased as the distance from the shed increased e.g. there were less hens in the outer range zone compared to the enriched and apron areas. The hens that travelled far from the shed (e.g. outer range) appeared to have benefited from improved feather conditions whereas the ones that stayed closer to the shed had greater feather damages. Many factors have been identified as the potential cause of the poor outdoor use in laying hens. These factors determine whether the range is attractive to the hens or not and the more favourable they are to the hens, the greater the chances that more hens would range. It was not possible to determine the strength of the influence of each of the factors on the ability of the hens to use the range in the current study but based on the established scientific evidence, one factor may be as important as the other in the level of influence on range use. The factors need to be considered carefully and independently when designing suitable outdoor range that have the potential to effectively encourage ranging activities in laying hens. Some important factors identified are genetics, climate, indoor stocking density, outdoor stocking density, flock size, age, tree cover and shelters, with their influence on range use found to influence the welfare condition of the hens e.g. the provision of cover trees in the range have been used to improve outdoor turn out, feather pecking behaviour and feather condition in laying hens. One of the limitations of this study was that the improved feather condition of the hens that used the outer range was not matched with an identification data that can be used to determine if the better feathered hens were regular outer range users.

Although this study was carried out on a fewer number of flocks of free-range laying hens compared to other published studies, it is generalizable in the sense that it represented Happy Egg system which is a brand of free-range system specific to Noble Foods Ltd. In addition to this, the findings of this study may also be generalized to the free-range system as it is consistent with the published evidence which reported that fewer hens in free-range system use the outdoor range, and that the hens that use the range prefer to stay close to their shed.

One of the challenges encountered in this study was the potential influence of the observers on the behaviour of the hens and to avoid this, a follow up study (presented in Chapter 6 of this thesis) was designed to utilize a technological aid (digital still camera) in the place of the direct observation method used in the current study. The digital still camera was chosen as it was likely to allow observations at a greater distance from the hens and may reduce observers' influence on the behaviour of the hens (as suggested by Cooper and Hodges, 2010).

Chapter 5

Validation of photography as a method of measuring hen behaviour

Photographic measure of chicken behaviour is considered a novel method as it has not been reported in the literature till date. For this method to be treated as a reliable measure of chicken behaviour, a validation study was carried out after the main study presented in chapter 7 this thesis had been completed. This validation study intended to verify if the data collected from the main photographic study was fit for analysis or whether data transformation was required. Still camera has been used in the study of wildlife behaviour (e.g. Long *et al*. 2008) and also for estimation of the population and distribution of commercial free-range chickens (e.g. Dawkins *et al*. 2003; Gebhardt-Henrich *et al*. 2014). However, no studies have reported its use in the observation of laying hen activities in the range and based on this, it is reported in this thesis as a novel technique for measuring laying hen behaviour. This chapter section deals with the protocols involved in the validation of photographic observation against a standard video method used in observing the behaviour of the laying hens in the range. The validation study was carried out on a 45-week old flock of Hyline laying hens after the main photographic-based behavioural study (presented in the chapter 6 of this thesis) had been carried out. The video used was recorded with a DS-7600 Series digital closed circuit television system (Hikvision Digital Technology, Hangzhou, China) connected to IR Mini Bullet Network Cameras (Hikvision Digital Technology, Hangzhou, China). The recorded video was digitally stored on a hard drive and replayed while screen shots of video frames was captured at 5 minute intervals (starting from 0.00 minute) to get the still images of the activities of the hens in the range. A total of

100 screen shots was gathered and the behaviour of 5 hens in each frame was sampled and recorded based on the same protocols and the ethogram (Table 3.27) used in the six-flock study reported in chapter 4 above. The video was then replayed and the behaviour of 5 hens (the same hens whose behaviour was sampled in the screen shots) was recorded.

Statistical analysis using Bland-Altman method

A Pearson product-moment correlation analysis was initially carried out on the data to test for the association between the photographic and video measures of the hen behaviours. A Bland-Altman procedure was carried out on the data to further test the level of agreement between the outcomes of the two behavioural measures used in this study. This procedure was proposed by M. J. Bland and D. G. Altman in 1983, based on the ground that the widely used correlation and regression analysis (e.g. the Pearson product-moment correlation analysis above) in the comparison of two measures can be misleading. The correlation and regression methods are useful in assessing the relationship between measures (e.g. photo and video measures) and do not measure if there was an agreement between them (Bland and Altman, 1983; 2003). Bland-Altman procedure has been widely used in clinical measurement studies involving the evaluation of new or alternative method of measurement or in the measurement and appraisal of differences between two instruments (e.g. Giavarina, 2015; Alsaedi, 2016). Giavarina (2015) strongly recommended the use of Bland-Altman procedure for the measurement of differences between two measurement methods and not the correlation methods that may produce unreliable results. It was argued that two methods used in measuring a particular variable may have a good correlation between them which simply states that they have similar variances but will not detect any systematic difference between the methods or any possible outlier (Bland and Altman, 1983).

In the current study, the photographic method of behavioural observation was compared with a standard video method and Bland-Altman plot was used to determine the level of agreement between the two methods and also determine if the photographic method can serve as a reliable alternative method or a potential replacement for the video method.

All the data was analysed using IBM SPSS 20.0 statistical software (IBM Corporation, Armonk, NY, USA). The SPSS does not currently have a direct procedure for computing the Bland-Altman plot and for this reason, other common functions e.g. transform compute, was used to achieve this. The transform compute variable function was used to create the *diff* variable (the difference between of the two measures of behaviour), achieved by subtracting the photographic values from the video measures. The behaviour of the hens assessed by the two measures involved counting of the number of hens out of possible 5, found doing each behaviour e.g. 2 resting + 1 locomotion and + 1 feeding/foraging + 1 comfort = 5.

$$diff = VideoBehaviour - PhotoBehaviour$$

A one sample t-test of the *diff* variable was carried out to determine if the difference between the two measures of behaviour was significant difference. A second variable, the mean of the measurements was also created and this was achieved by adding the two measures and dividing by two.

$$mean = \frac{PhotoBehaviour + VideoBehaviour}{2}$$

The null hypothesis H_0 would mean that there is no statistical difference between the two measures (video and photo methods), whereas the alternative hypothesis would mean that there is a significant difference between them. The null hypothesis would be rejected and alternative hypothesis H_1 retained when there was a statistical difference between the two measures but would be retained when there is no significant difference between the two methods of behavioural observation.

However, it is important to ensure that the *diff* data obtained by transform compute function was normally distributed and for this reason a normality test was carried out on the data by plotting the histogram of the differences between the two measures for each category of behaviour before the data was analysed further.

Assessing bias and agreement limits between photo and video methods

Ideally, it the result of the photographic measures of behaviour was expected to be similar to that of the standard video method and in this case, the difference between the two sampling methods would be close to zero. However, the use of different measures of behaviour potentially introduces some degree of error due to their inherent imprecisions, which in turn generates the variations in their results. To estimate the level of agreement between the video and photographic measures of behaviour used in this study, the difference between the two paired methods was plotted against their mean in a simple XY scatter plot i.e. Y-axis shows the difference between the methods and the X-axis represents the mean of the measures. The plot of difference against mean determines if there is any relationship between the measurement error (difference) and the true value (mean). The statistical limit of agreement was determined using the mean difference ($\bar{d}$) and the standard deviation (s) of the differences between the two measurements to estimate the upper and lower confidence limits. Three horizontal lines were added to the graph to represent the mean of the difference between the methods (middle), upper (upper positive line) and the lower (lower negative line) confidence limits. According to Bland and Altman (1983) the differences was expected to fall between $\bar{d}$ -2s and $\bar{d}$ +2s or more precisely 95% between the $\bar{d}$ $+1.96s$ (upper limit) and $\bar{d}-1.96s$ (lower limit).

The Bland-Altman plot simply is used to estimate the bias and the range of agreement (upper and lower limits) and does not state if the level of agreement between the video and photo methods of observations are sufficient or whether the photo method is a suitable alternative or a good replacement for the standard (video) method of monitoring animal behaviour. For this reason, the proportional bias was estimated for each behaviour using a linear regression procedure. The linear regression analysis of the differences (*diff*) between the paired methods and the means of both methods was carried out on all the observed behaviours. The difference between the methods was treated as the dependent variable whereas the mean was treated as the independent variable in the procedure and this procedure was meant to determine if there is any difference between the upper and lower confidence intervals e.g. if there was any difference in the data points between the upper and lower mean difference lines.

For this analysis, a null and alternative hypothesis were created. The null hypothesis would be that there will be a coefficient of zero and a significant t-score whereas the alternative hypothesis would be that the coefficient is not zero and that the t-score is not significant. The null hypothesis will be rejected if the regression coefficient is not zero and also if the t-score is not significant and this would mean that there are no trends or proportional biases between the photographic and video methods of observing chicken behaviour.

Results of the T-tests, correlation and regression analysis for each of the measured behaviour

The Pearson correlation coefficient showed that there are strong positive correlations between the video and photographic measures of resting ($r = 0.746$, $p < 0.001$, $n = 100$) and locomotory ($r = 0.706$, $p < 0.001$, $n = 100$) behaviours whereas moderate positive relationships were found in foraging ($r = 0.623$, $p < 0.001$, $n = 100$) and comfort ($r = 0.680$, $p < 0.001$, $n = 100$) behaviours. These results showed that the outcomes of the video and photographic measures of resting, foraging, locomotory and comfort behaviours are correlated but it did not explore the validity of the photographic method as a tool in assessing the behaviour of laying hens.

After the *diff* (difference between the two methods of behaviour observation) and *mean* (the mean of the two methods of behaviour observation) variables were created, a one sample T-test of the *diff* was carried out and the results of the analysis showed that there was no significant difference between the photographic and video measures (Table 5.0) for the resting, foraging, locomotion and comfort behaviours. This result suggested that the use of both methods i.e. photographs and videos, in measuring the behaviour of laying hens yielded similar outcomes although further testing is required before a conclusion is drawn.

Behaviour	**Mean difference**	**T-value**	**P-value**	**SEM**
Resting	0.12000	1.588	0.116	0.07559
App/Foraging	-0.09000	-1.136	0.259	0.07926
Locomotion	-0.02000	-0.223	0.824	0.08987
Comfort	-0.01000	-0.445	0.657	0.02245

Table 5.0 The results of the t-test for the mean difference between the video and photographic measures of behaviours. There was no significant difference between the photo and video methods used in measuring resting, foraging, locomotion and comfort behaviours.

The Bland-Altman plot also showed that there was no wide difference in the agreement between the video and photographic measures of behaviour and this suggested that there was no large discrepancy between the two methods used in observing the behaviours of the laying hens (Table 5.1).

	Video method		Photographic method	
Behaviour	**Mean (%)**	**SEM**	**Mean (%)**	**SEM**
Resting	35.20	2.05	32.17	2.17
Foraging	26.00	1.81	27.80	1.84
Locomotion	37.20	2.13	37.60	2.48
Comfort	1.60	0.55	1.80	0.58

Table 5.1 Showing the mean proportions of each behaviour measured with video and photographic methods. The table suggested that the outcome of the photographic method was similar to that of the standard video method of behaviour observation.

The narrow confidence limit reported was consistent in the measures of the resting (Figure 5.0), foraging (Figure 5.1), locomotory (Figure 5.2) and comfort (Figure 5.3) behaviours. The discrepancy between the two methods of behavioural observation was greatest in the locomotory behaviour and least in the comfort behaviour and this suggested that data dispersion (difference between the largest and smallest values) was greatest in the locomotory behaviour and least in the comfort behaviour. This could be because the hens performed least comfort behaviour but engaged in greater locomotory activities in the range. In addition, there were no trends as the difference between the two measures was similar on both sides of the mean line of the Bland-Altman plots. There was also a consistent distribution of data points across the graph with most of the points found to concentrate around the mean line for all the behaviours e.g. there were not many outliers in the plots. It is important to note that the validation study discussed here consisted the sampling of the behaviour of 5 hens within the video and photographic frames. The implication of this is that the frequencies of each behaviour can only fall between 0 and 5, thus resulting in a non-continuous dataset. The results of frequency distribution of the *diff* and *mean* variables of different behaviours (See Appendix) showed that *diff* variable had values between -2 and +2 which varied in their relative abundance e.g. 0 value had the greatest frequency, ranging from 38 to 95% of the total of the behaviours recorded. The *mean* variable had values between 0 and 4.5, with variations in the frequencies of the values between behaviours (e.g. 0 value had frequency value ranging from 1 to 89%). This constraint to the dataset had resulted in the relatively fewer data points seen in Figures 5.0, 5.1, 5.2 and 5.3 of the Bland-Altman plots instead of the many data points in the *diff* and *mean* variables. The fewer data points suggested that the data points are on top of each other, as individual numbers appeared many times within each variable.

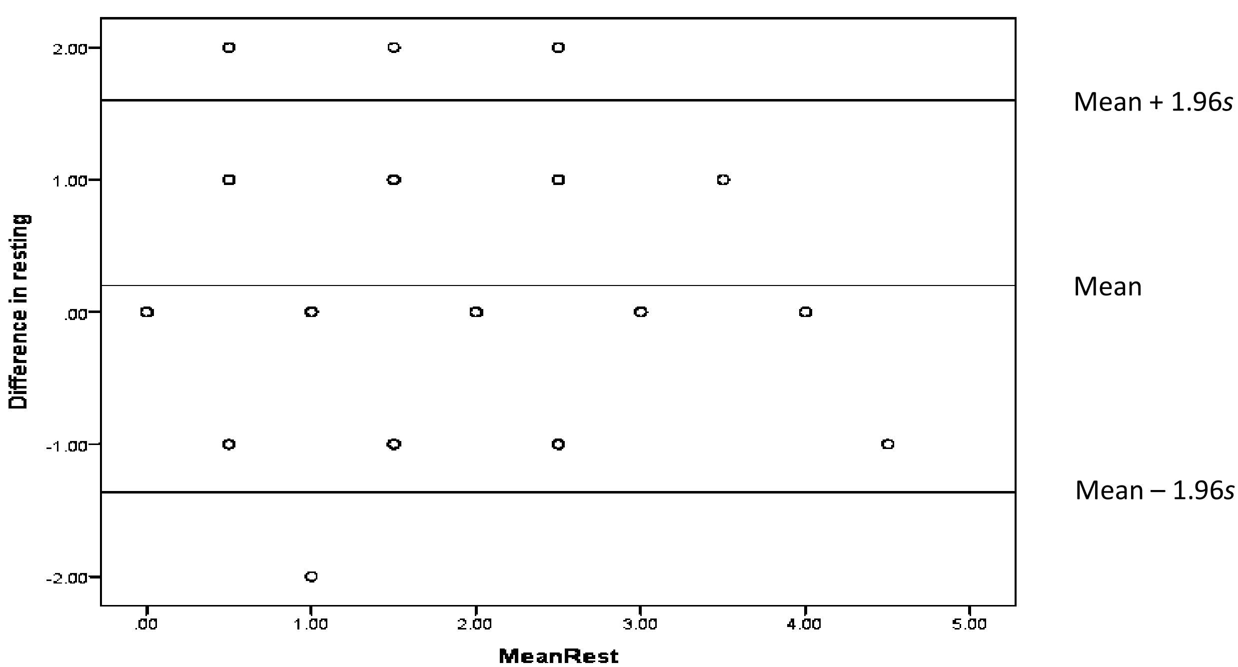


Figure 5.0 The Bland-Altman plot showed that there were no large discrepancies between the photographic and video methods used in observing resting behaviour in this study.

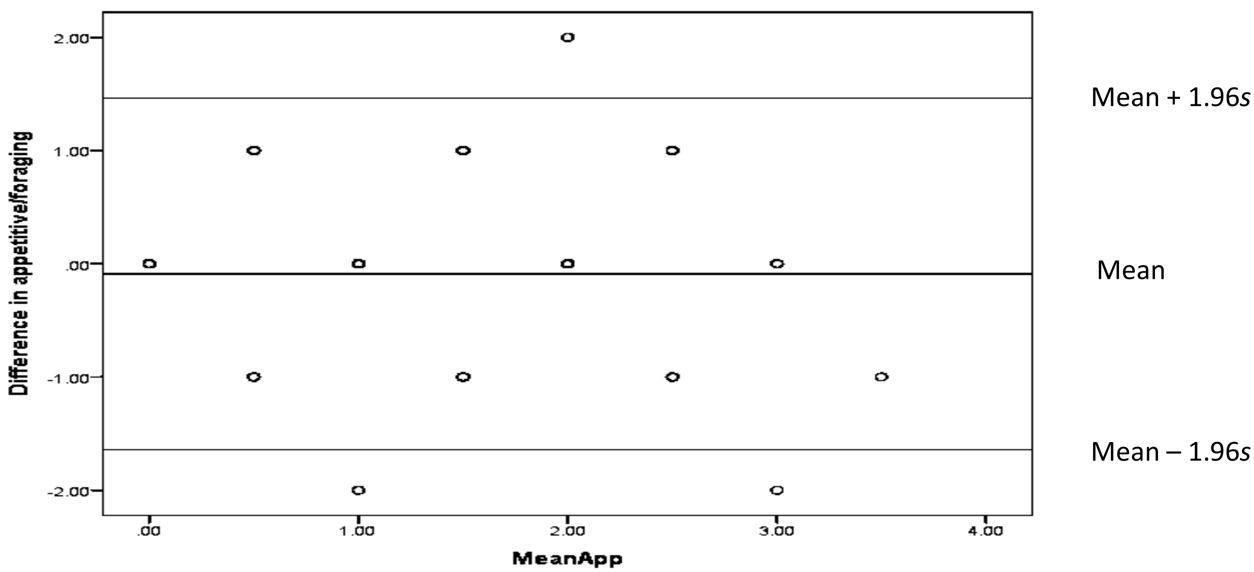


Figure 5.1 The plot revealed that the discrepancy between the photographic and video methods was not large for the observation of foraging behaviour recorded in this study.

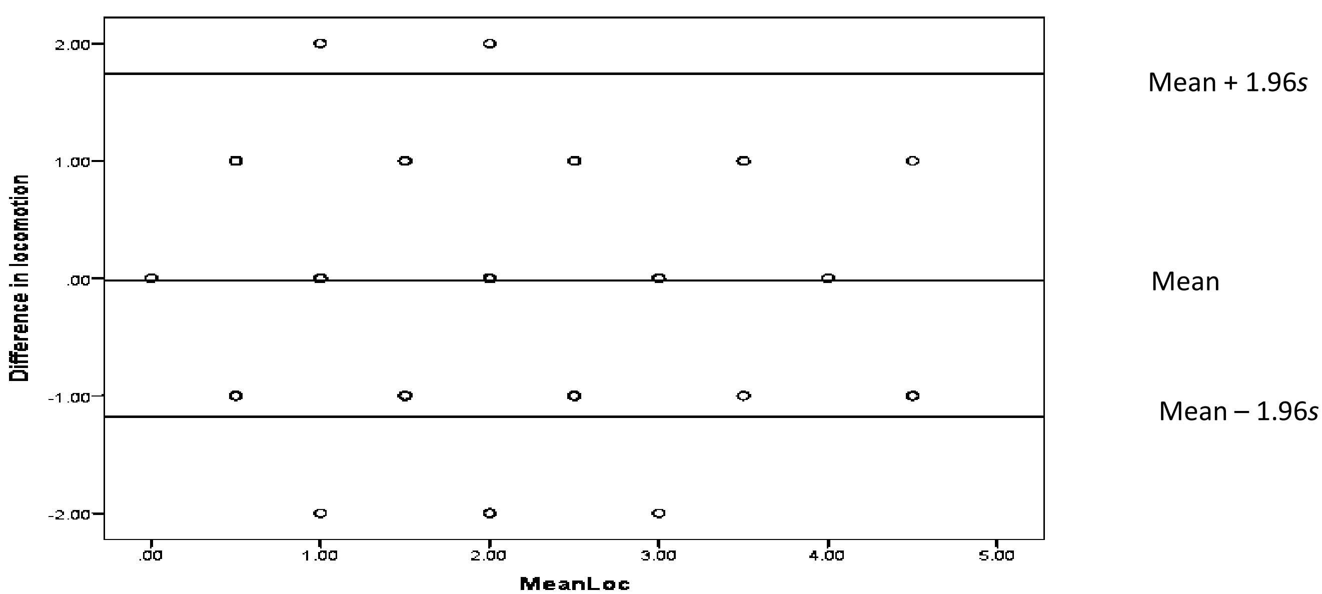


Figure 5.2 The discrepancy between the outcome of photo and video observation methods was not large for locomotory behaviour as also seen in the behaviours above. Locomotory behaviour had the largest discrepancy.

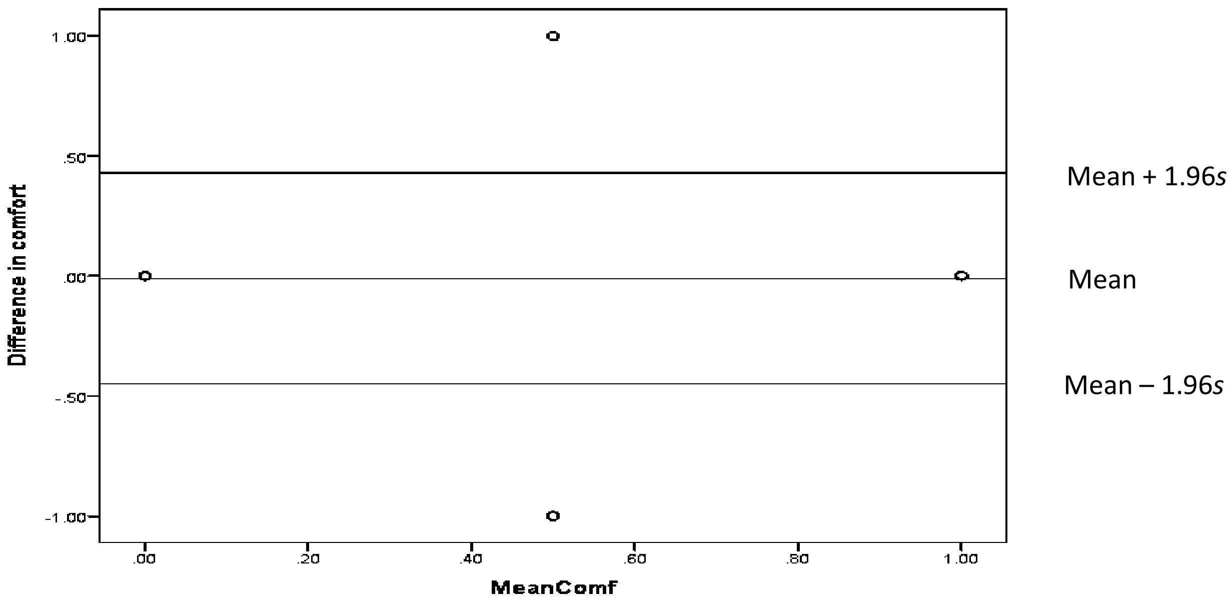


Figure 5.3 The gap between the outcome of photographic and video methods of behavioural observation was least in the comfort behaviour recorded with values less than < ± 0.5.

The results of the regression analysis of difference between the methods and their means showed that the coefficients were not zero but that the t-scores were non-significant for all the behaviours recorded (Table 5.1). For the above stated reason, the null hypothesis was rejected and the alternative hypothesis was accepted. The acceptance of the alternative hypothesis indicated that there were no trends or proportional biases between the two methods of observation used in this study and based on this, it is concluded that there was an agreement between the photographic and video methods of behavioural observations in laying hens. This results also suggested that photographic behaviour observation is a good alternative or replacement for the standard video observations.

Behaviour	Coefficient	T-value	P-value
Resting	-0.066	-0.861	0.391
App/Foraging	-0.021	-0.214	0.831
Locomotion	-0.080	-0.616	0.330
Comfort	-0.064	-0.722	0.472

Table 5.1 Table showing the regression coefficients for resting, foraging, locomotory and comfort behaviours. There was a

Conclusion

The Bland-Altman procedure showed that the use of photographic method for the observation of hen behaviour in the range yielded similar result as the video observations. This further suggested that there is a good agreement between the two methods used in the behaviour study of the free-range laying hens. Based on this evidence, it can be concluded that the use of still digital photographs in the study of laying hen behaviour can be used as an alternative for the standard video method.

Chapter 6

Methodological development of the photographic observation

In preparation for the second main study, a flock commercial laying hens near Heckington Fen in Lincolnshire was visited after permission was obtained from the Noble Food farmer. The laying flock was visited at 54 weeks of age and the aim of this mini study was to establish and refine the methodological protocols involved in the use of still digital camera and also identify the potential flock for the main study ahead of farm visits. The study was carried out using a flock of 7860 laying hens prior to obtaining the authorization to access the young flock intended to be used for the main study. The experimental protocols were designed and repeatedly carried out on the similar scale as the main study. The study consisted of the mapping out phase of the outdoor runs carried out with measuring tape and bamboo poles. The bamboo poles were used to mark twenty 10m x 10m quadrats in each outdoor zone lined in a straight transect lines around the sides of the shed. The flock was walked, starting from the apron through to the outer range zone and the hens in each of the quadrats were photographed twice during each visit. The photographs were taken at 9am, and 10am during each visit at a distance of 15 metres from the hens. The photos were saved in a PC, ready for sorting, data extraction and analysis.

Data extraction and analysis

The photographs were viewed in the PC and the number of hens within each quadrat of the quadrats was counted and recorded alongside the behavioural patterns of 5 selected hens. The behaviour of the hens was identified when photographs are zoomed using the same ethogram as the six flock study (Table 3.27). The range use and behaviour data was analysed for the descriptive statistics only and the result was used as a guide for planning the larger study.

Results and discussion

The results showed that there were more hens in the apron zone (24.72 ± 0.832 hens/quadrat) compared to the enriched (13.38 ± 0.524 hens/quadrat) and outer range (3.37 ± 0.195 hens/quadrat) areas. The distribution of the hens in the range showed that the hens clustered around their shed and decreased with increased distance from the shed. The hens were likely to engage in foraging behaviour (35.23 ± 0.882%), followed by locomotion (33.0181 ± 0.802%), resting (28.76 ± 0.870%) and comfort (2.98 ± 0.301%) behaviours, with no aggression recorded. Foraging behaviour was recorded most in the outer range zone (36.23 ± 1.547%), followed by the enriched (35.38 ± 1.549%) and apron (33.93 ± 1.486%) zones and similar pattern was found in the proportion of locomotion i.e. outer range zone (34.46 ± 1.592%), followed by the enriched (33.37 ± 1.570%) and apron (31.23 ± 1.592%). Resting and comfort behaviour were recorded most in the apron as opposed to the foraging and comfort behaviours. The proportion of resting in the apron was (30.18 ± 1.424%) compared to the enriched (29.70 ± 1.381%) and the outer range areas (26.39 ± 1.361%). Comfort behaviour was the least recorded behaviour and was found to occur most in the apron (3.95 ± 0.582%), intermediate in the enriched (3.00 ± 0.545%) and least in the outer range zone (2.98 ± 0.423%). The results showed that there was an agreement between the outcome of this mini study and the other reports (Nicol *et al*. 2003; Hegelund *et al*. 2005; Nagle and Glatz, 2012; Hartcher *et al*. 2015) which reported that laying hens showed increased use of the area surrounding the shed. The hens appeared to prefer staying close to the shed in all reported cases and the reason for this can include but not limited to the potential fear associated with range use (Hartcher *et al*. 2015), safety (Nagle and Glatz, 2012) and cover (Nicol *et al*. 2003; Hegelund *et al*. 2005). The result of the behavioural studies showed that the hens foraged most but showed reduced comfort behaviour thereby suggesting that although the hens relied on comfort activities in the range, they are more likely to explore their environment. The hens foraged most in the outer range but engaged in greater comfort activities in the apron and this may have been a result of social influence or the differences in resource availability between the outdoor zones.

Conclusion

The evidence obtained from this mini study showed that the hens generally used the area immediate to their shed compared to the distant areas where they were sparsely populated. There was an indication that the hens were attracted to the close proximities of the shed. The behaviour of the hens suggested that there is a need to improve the usage of the distant areas of the range. The evidence showed that the photographic method intended for the main study would be successful as the report of this study was consistent with other studies that investigated range use in laying hens.

Chapter 7

Study of the temporal pattern of range use and the behaviour of a single flock of free-range laying hens from initial range access, using photographs

This study was designed to address the issue of observer influence on the hens, which was encountered during the six-flock study presented in chapter 4 of this thesis. It comprised of a large prospective study of a single flock of Happy Egg (free-range) laying hens in commercial. The study explored the use of range and the behaviour of the hens over a 15-week period starting on the day of initial outdoor access and assessed the temporal pattern of range use by the hens. Similar quadrat and transect techniques described in the six-flock study (presented in chapter 4 of this thesis) was utilized in the current study, alongside a digital camera (Figure 7.1) to explore the weekly changes in the ranging behaviour of the hens. The materials and methods of data collection, extraction and analysis is presented in this chapter, followed by the presentation of the results, discussions and conclusions of the findings in relation to other published evidence.

A validation study was carried out and presented in chapter 5 of this thesis to determine the reliability of the use of photographic method in observing hen behaviour. The study showed that the use of still photographs is a valid and acceptable method of behaviour observations and can therefore serve as an alternative and/or a replacement for the video method of studying hen behaviour.

Research hypothesis

The ranging pattern of a single flock of laying hens was studied and the effect of week of access, outdoor zone and time of the day on the outdoor turnout was explored. The null hypotheses (H_o) for this study stated that week of access, zone and time of the day will have no effect on the behaviour and number of the hens in the range whereas the alternative hypothesis (H_1) stated that the behaviour and outdoor use will be influenced by the week of access, outdoor zone and time of the day. The choice of hypothesis was determined by the outcome of the study.

Materials and methods

The hens and their husbandry system

This major study was carried out on a single flock of Hyline laying hens managed by Noble Foods UK Ltd in Lincolnshire. The flock was made up of 3958 free-range laying hens at their early lay period housed in a large shed and kept indoors for the first two weeks of arrival before being allowed access into the range at 20 weeks of age. The flock was observed for 15 weeks from the day of initial outdoor access, using a digital still camera. The hens were housed and managed according to the Council Directive (1999/74/EC), Lions Food Code of Practice BEIC (2013), RSPCA's welfare standards for laying hens (RSPCA 2013) and Happy Egg Specifications (See appendix). The house provided a scratch area on one end of the shed with dry loose litter and nest boxes from which eggs conveyed to the packing station located at the entrance of the shed. Nipple drinkers and feeders were provided for the hens and they allowed easy and *ad libitum* access to food and water to all the hens throughout this study. There were pop holes located on both sides of the shed which allowed the hens access into the range they have access to activity kits (enrichment resources) provided as part of the Happy Egg requirements. The hens were allowed unrestricted day time access (up to 9 hours per day) to the range and there were cover trees on the sides of the shed.

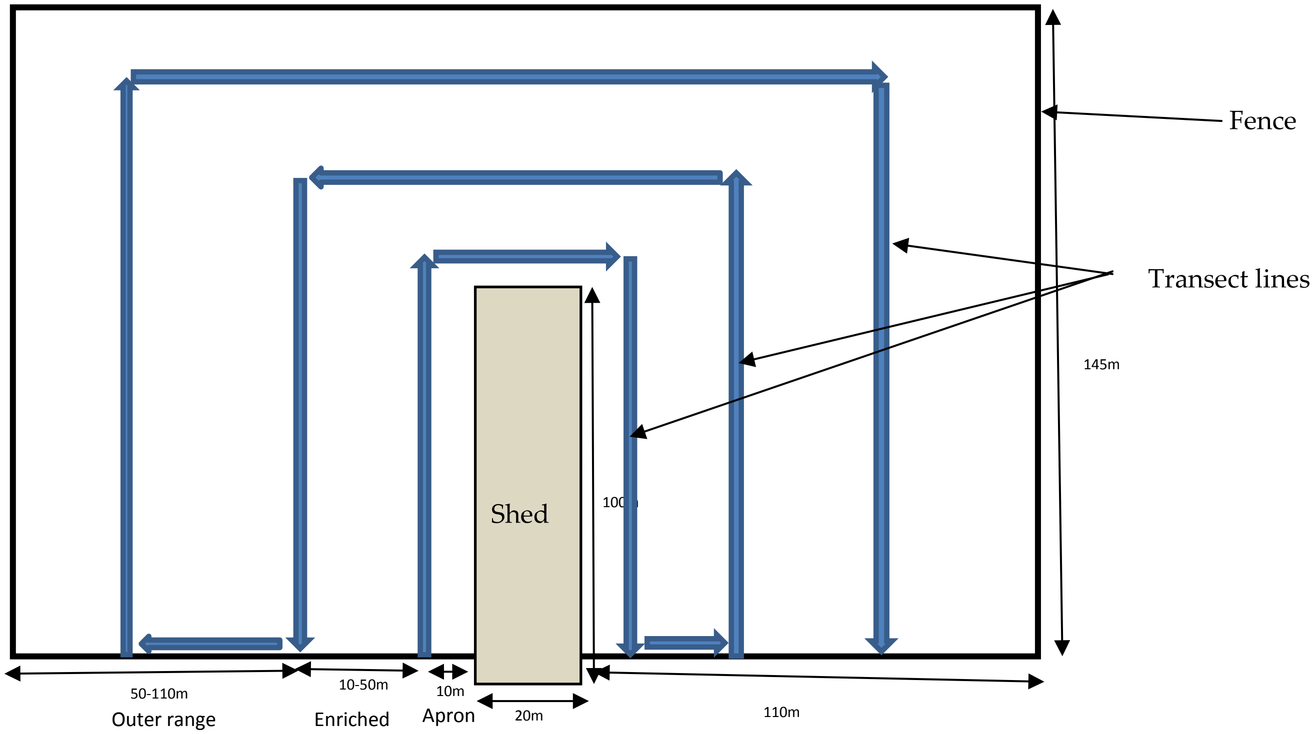


Figure 7.0 The arrangement of 3 transect lines (20 equal sized quadrats per transect) around the shed of the 4, 000 hen laying flock. The arrows shows the direction of walks during photographic observations in the range.

Data collection period

The flock was observed during the 15-week period to determine the weekly pattern of range use by the hens. The flock was visited twice every week to improve validity and reliability of the data and farm visits started in June and ended in October 2013 between morning hours i.e. 9am (when the pop holes were opened) till 2pm. During farm visits, boots, bamboo poles and hand gloves used were all dipped in disinfectants to ensure good compliance to Noble Foods biosecurity requirements.

Mapping out of outdoor zones into transects and quadrats

The range was divided into three distinct zones comprising of the apron (the immediate area surrounding the shed to 10m from the side of the shed); the enriched zone (with enrichment resources e.g. perches, cover trees, mini sheds, dust baths, covering 10 and 50 metres from sides of the shed) and the outer range zone (covering the distant part of the range, found from 50 metres to the end of the range). The quadrats were measured using a measuring tape and marked with bamboo poles and were laid out around the shed in three transect lines, one in each outdoor zone. Twenty quadrats were laid in each outdoor zone (apron, enriched and range) to give a total of 60 quadrats and each quadrat was photographed at hourly intervals using Sony-α 37 digital camera, between 9am and 2pm during each visit. All the quadrats were marked with bamboo poles for ease of identification and thus enabled the exact location of the hens to be determined e.g. if hens were within or outside the quadrats, during the head counting of the hens in the photographs. For hens to be counted, majority of its body must be within the quadrat line e.g. at least half of its body must be in the quadrat.

Figure 7.1 Sony-α 37 digital camera used for the behaviour observation of the hens.

Weather station

Weather conditions have been reported to influence range use in laying hens (e.g. Richards *et al*. 2011; 2012; Gilani *et al*. 2014) and to establish the link between the number of hens found in the range, the local environmental temperature, RH and wind speed of the study location was measured using a common digital indoor/outdoor wireless weather station (Figure 7.2) with PC interface. The weather station was made up of indoor and outdoor components and before data collection started for each visit, the outdoor component was mounted in a designated position, half way between the shed and end of the outer range and the indoor component kept in the egg packing station. The weather variable data i.e. temperature, relative humidity (RH) and wind speed was recorded every 10 minutes and transmitted wirelessly from the outdoor unit to the indoor component where it was temporarily stored. Effective transmission was ensured by maintaining the distance between the indoor and outdoor components at 100m based on the manufacturer's recommendations. At the end of each day's visit, the indoor unit was connected to a PC where weather software (Easyweather) was installed and all the data exported into the PC in readable excel format.

Figure 7.2 The wireless weather station with an indoor (a) and outdoor (b) units.

Photographic data collection techniques

A photographic sampling technique was used to investigate the behaviour and outdoor use of the hens at the point of initial outdoor access in a commercial setting. Dawkins *et al*. (2003) used similar technique to study the ranging behaviour of free-range broilers although a slightly different approach was used in this study. Before the first data was collected on the farm, every part of the outdoor area was walked to habituate the hens to the observer's presence. The Photograph of the hens in all the quadrats located in the three outdoor zones was taken with the digital camera mounted on a tripod and stored. The photographs were taken in such a way that each one covered an entire quadrat. Photographs were taken every hour for 5 times during each farm visit and the data collected started from the quadrats in the apron, then the enriched and lastly the outer range zone. The sampling bouts were carried out at five designated times starting from 9am through to 2pm. The photographs were taken at the hen-observer distance of 15m to further minimize the influence of the observer on the hens. The photos were stored in a computer hard drive and ready for sorting and data extractions.

Data extraction protocols from the photographs

Range use data was extracted from a total of 9,000 (i.e. 20 quadrats x 3 zones x 5 hrs photos x 2 visits/week x 15 weeks) photographs collected during this study. All the photographs were saved and sorted according to the outdoor zones, experimental week and time of the day before data extraction. The photographs were individually viewed on the PC and the number of hens within the quadrat of each photographic frame was counted.

The behaviour of 5 selected hens in each of the photographic frames was recorded based on the ethogram presented in the six-flock study (Table 3.27) for the identification of all the behaviour categories. The hens closest to the observer (reference hen) was selected and its behaviour recorded. The behaviour of every second hen from the reference hen was sampled in succession until 5 behaviour samples were achieved. The behaviour data was recorded and coded with information on the location of the hen, time of the day and week of outdoor access and analysed in line with the aims and objectives of the current study.

During behaviour data extraction, all the photographs were zoomed until the behaviour of the selected hen was clear enough to be identified. However, the zooming of the photographs during behaviour sampling was time consuming but the data generated from the photographs was worth the effort.

Behaviour of the hens in the photographs

The photographs (Figure 7.3 to 7.10) below are presented as the illustrations of the mutually exclusive behaviours recorded during the study. Some of the behaviours were identified only when the photographs were zoomed (e.g. preening, stretching) and for this reason only the behaviours that were identified without zooming are presented below.

Figure 7.3 The hens labelled (a) and (b) engaging in locomotion whereas hen (c) was performing foraging behaviour. Hen (a) was walking i.e. moving slowly, with the first foot put down on the floor before the second one is lifted; (b) was flying i.e. moving actively in the air with the wings; (c) was performing ground pecking behaviour, with pecks directed to the ground.

Figure 7.4 The hen labelled (d) engaging in foraging behaviour involving ground scratching i.e. stepping backwards with the feet raking across the floor.

Figure 7.5 The hens labelled (e) and (f) were resting whereas hen (g) was performing comfort behaviour. Hen (e) was sitting, with the body and both hocks touching the floor underneath; (f) was standing and not moving the feet or the body touching the floor (g) was stretching, with the leg elongated and not associated with walking.

Figure 7.6 The hen labelled (h) performing foraging behaviour involving walking while pecking on grasses.

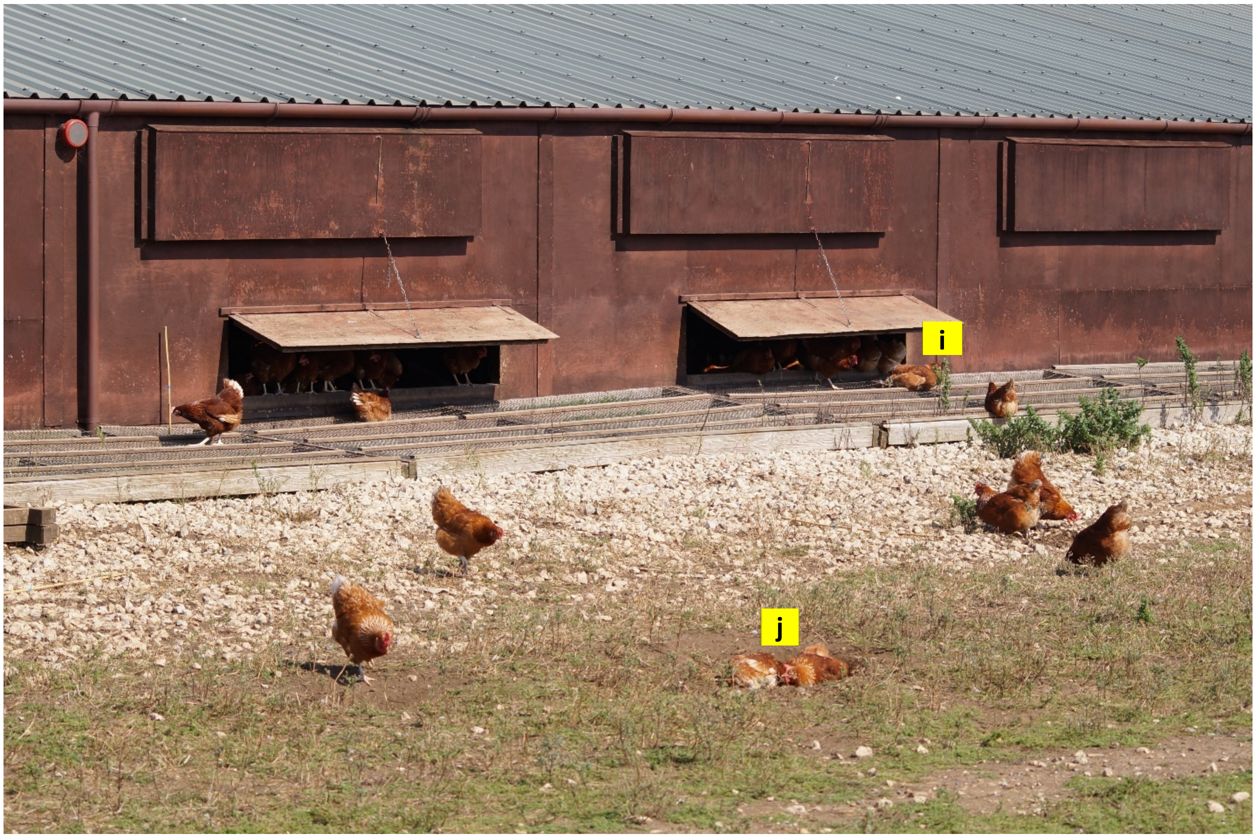


Figure 7.7 The hens labelled (i) and (j) were resting. Hen (i) was lying on its side, with both feet on the same side of the bird; (j) was performing dust bathing (comfort behaviour) with foot scratching and bill-raking the loose soil, followed by vertical wing shaking, head rubbing, bill-raking whilst lying.

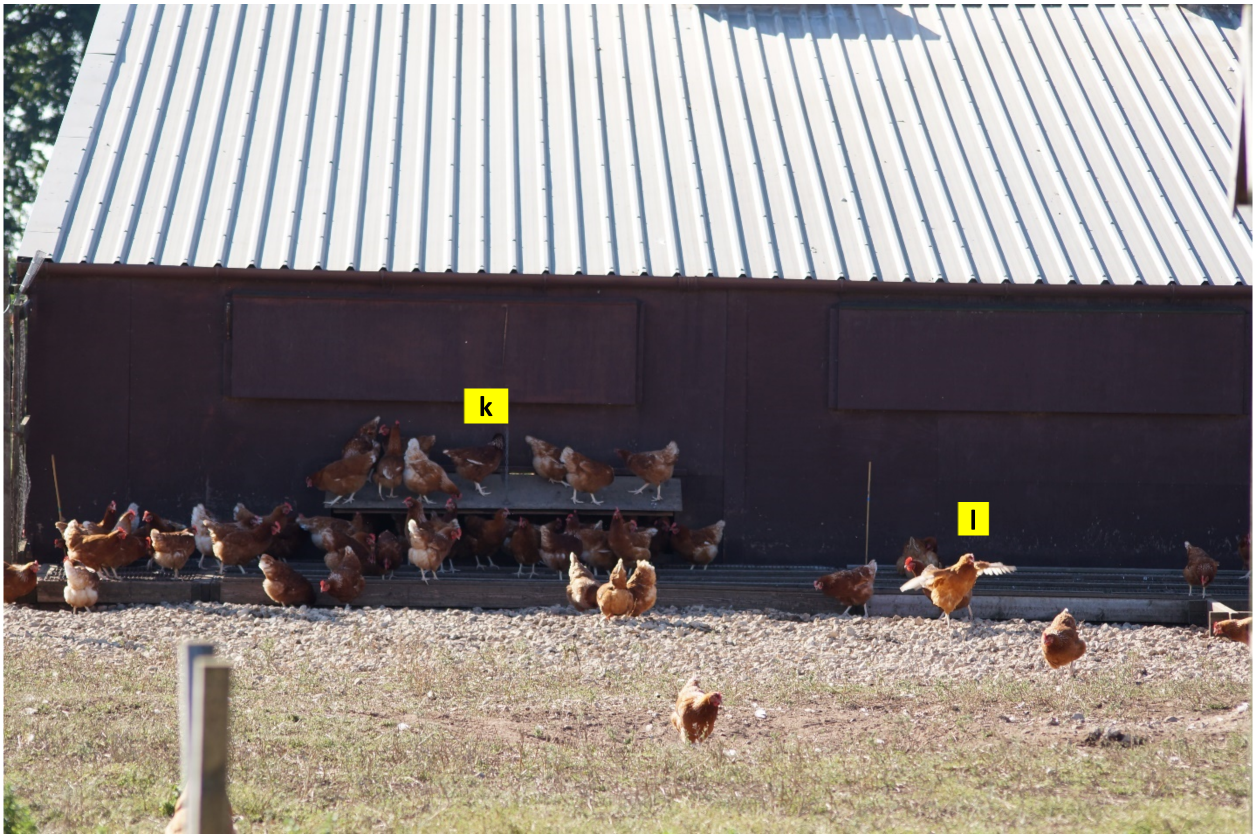


Figure 7.8 The hens labelled (k) and (l) were performing resting and comfort behaviours respectively. Hen (k) was perching i.e. standing on the pop hole flap above the ground; (l) was performing wing flapping with both wings.

Figure 7.9 The hen labelled (m) was performing dust bathing (comfort behaviour) with foot scratching and bill-raking the litter or lose soil, followed by vertical wing shaking, head rubbing, bill-raking whilst lying.

Figure 7.10 The hen labelled (n) was preening (comfort behaviour) with the beak being moved over the feathers.

Statistical analysis

All the data collected for this study was analysed using IBM SPSS 20.0 statistical software (IBM Corporation, Armonk, NY, USA). Validation of each model (range use and behaviour) was carried out using histogram plots, before further GLM analysis was carried out and based on the outcome (See Appendix) the data was normally distributed and for this reason no that data transformation was required prior to further analysis.

Range use data was explored for descriptive statistics, followed by a general linear model analysis of variance (GLM ANOVA) approach used to explore the effects of the explanatory variables (outdoor zone, time of the day, week of outdoor access, temperature, RH and wind speed) on the distribution of the hens in the range. The outdoor zone, time of the day and week of range access was treated as fixed factors whereas temperature, wind speed and RH were fitted as covariates in the model. A step-wise model simplification approach was used in the GLM and it involved the exclusion of the non-significant main effects and interactions on a step-by-step basis ($p > 0.05$) until a fitted model was achieved.

The sum of each behaviour per quadrat was calculated by adding up their frequencies in each quadrat, followed by its conversion to percentages achieved by dividing the sum of the behaviours with total possible outcome (5 behaviours) per quadrat then multiplying by 100. A descriptive statistics of the behaviour data was explored to quantify the occurrence of each of the behaviours (resting, foraging, comfort, aggression and locomotion) in the range. Data analysis was carried out using a similar GLM approach as in the range use model above. The model explored the effects of outdoor zone, time of the day and week of outdoor access on each of the behaviour and the fixed factors and covariates were also similar to that used in the range use model above. A separate GLM was developed for each of the behaviour and the effect of the predictable variables tested in all the models.

Bonferroni correction was applied in the pair wise *post hoc* tests carried out on significant factors and the results of the distribution and behavioural analysis were presented below in the forms of the means and standard error of means for the main effects and their interactions.

Summary of the results

For distribution analysis, the factors retained in the fitted model were the zone, time, week, temperature and wind speed with significant effects on the distribution of hens in the range (See Appendix). However, RH had no effect on distribution of hens in the range and based on this, it was excluded from the fitted model. In this study, the detailed impact of outdoor location, time of the day, week of range access, temperature, relative humidity and wind speed on the distribution and behaviour of the hens in the range is presented. The results showed that the hens preferred the locations closer to the shed to the farther areas of the range which means that the number of hens outdoors decreased with increased distance from the shed. The hens used the range most in the morning compared to the afternoon periods suggesting that the hens were more likely to leave the shed in the morning and least in the afternoon. The management practice required that hens be kept in the shed for the first 20 weeks of age (rearing period) before being let out into the range and there were indications that the hens were reluctant to leave the shed in the early weeks of range access (i.e. in first two weeks) but there were more hens outdoors as the study period progressed. During the earlier weeks of observations, the hens that used the range were found only in the apron zone with no hens found in the enriched and outer range areas. The hens progressed unto the enriched belt in the third week of access and the outer range zone was accessed in the fourth weeks of access. Outdoor temperature and wind speed had negative impacts on range use whereas the number of the hens outside the shed was not influenced by the outdoor RH. While there was no aggressive behaviour recorded during this study, the hens were more likely to perform to locomotory behaviour followed by foraging, resting and comfort behaviours respectively. The behaviour of the hens was influenced by their location in the range with resting and comfort behaviours found to occur most in the apron zone whereas foraging behaviour and locomotory behaviours were recorded most in the outer range zone. Resting and comfort behaviours decreased whereas locomotion and foraging behaviours increased as the weeks of access progressed. There was daily variation in the proportion of foraging behaviour whereas resting, locomotion and comfort behaviours remained constant through the day. Temperature, RH and wind speed had no effect on the behaviour of the hens.

Distribution of the hens in the range

The result of the analysis of the range use data showed that the hens were unevenly distributed in the range indicating that there was a significant effect of location on the number of hens found across the entire range i.e. apron, enriched and outer range zones ($F_{2,8939} = 24.075$, $p < 0.001$). Majority of the hens in the range were found in the apron zone followed by the enriched and outer range zones respectively. The results further revealed that at the time of this study, the number of hens found in the range decreased as the distance increased from the shed (Figure 7.11) and this suggested that the hens utilized the apron most compared to the enriched and outer range areas and with greater use of the enriched zone compared to the outer range area.

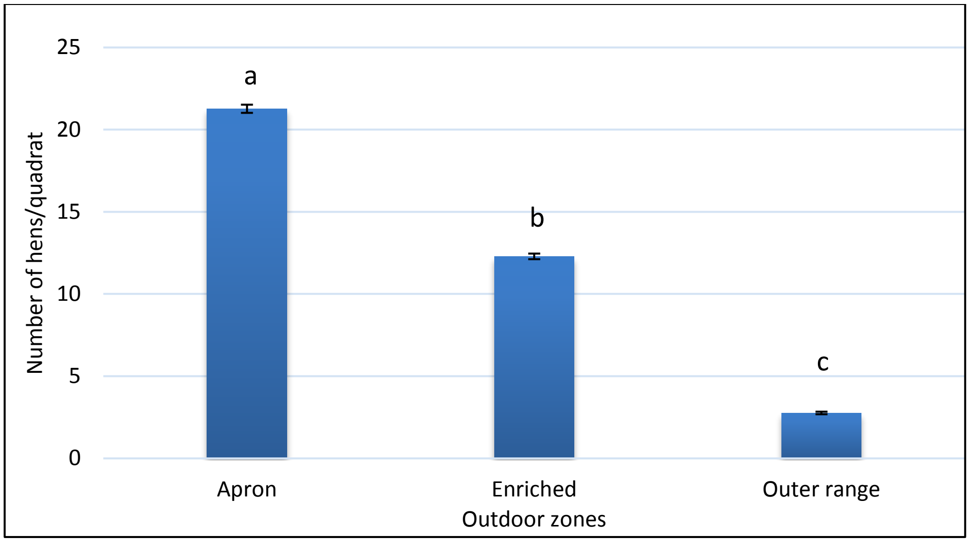


Figure 7.11 Showing that the number of hens in the range decreased with increasing distance from the shed. [a,b,c] Means that zones with different superscripts are significantly different ($p < 0.001$)

Effect of the week of access on outdoor use

The hens were allowed access to the range at 20 weeks of age and the weekly record of outdoor use showed that weekly range use changed from one outdoor zone to another and vice versa. There was a significant two-way interaction between week and zone ($F_{28,8939} = 37.174$, $p < 0.001$) which indicated that weekly outdoor use varied between the outdoor zones and also that the use of apron. The difference in the outdoor use (mean number of hens per quadrat) between the weeks of access was significant in the apron ($F_{14,2985} = 16.044$, $p < 0.001$), enriched ($F_{14,2985} = 85.868$, $p < 0.001$) and outer range ($F_{14,2985} = 127.879$, $p < 0.001$) zones. This indicated that weekly range use differed between all the outdoor zones e.g. the hens were found to use only the apron zone in the first two weeks of range access and progressed unto the enriched and outer range zones in the third and fourth weeks of access (Figure 7.13). The difference in the quadrat use between the three outdoor zones was significant for all the weeks of range access i.e. week 1 ($F_{2,597}$ = 441.209, $p < 0.001$), week 2 ($F_{2,597} = 491.546$, $p < 0.001$), week 3 ($F_{2,597} = 444.383$, p <

0.001), week 4 ($F_{2,597} = 402.659$, $p < 0.001$), week 5 ($F_{2,597} = 361.719$, $p < 0.001$), week 6 ($F_{2,597} = 361.243$, $p < 0.001$), week 7 ($F_{2,597} = 370.257$, $p < 0.001$), week 8 ($F_{2,597} = 258.712$, $p < 0.001$), week 9 ($F_{2,597} = 96.156$, $p < 0.001$), week 10 ($F_{2,597} = 268.800$, $p < 0.001$), week 11 ($F_{2,597} = 206.855$, $p < 0.001$), week 12 ($F_{2,597} = 77.923$, $p < 0.001$), week 13 ($F_{2,597} = 61.562$, $p < 0.001$), week 14 ($F_{2,597} = 187.087$, $p < 0.001$) and week 15 ($F_{2,597} = 104.254$, $p < 0.001$). These results suggested that there were more hens/quadrat in the apron compared to the enriched and outer range zones and also there were more hens in the enriched area compared to the outer range zone in all the weeks of range access exception week 1 and 2 when no hen was found in the enriched and outer range zones (Figure 7.12).

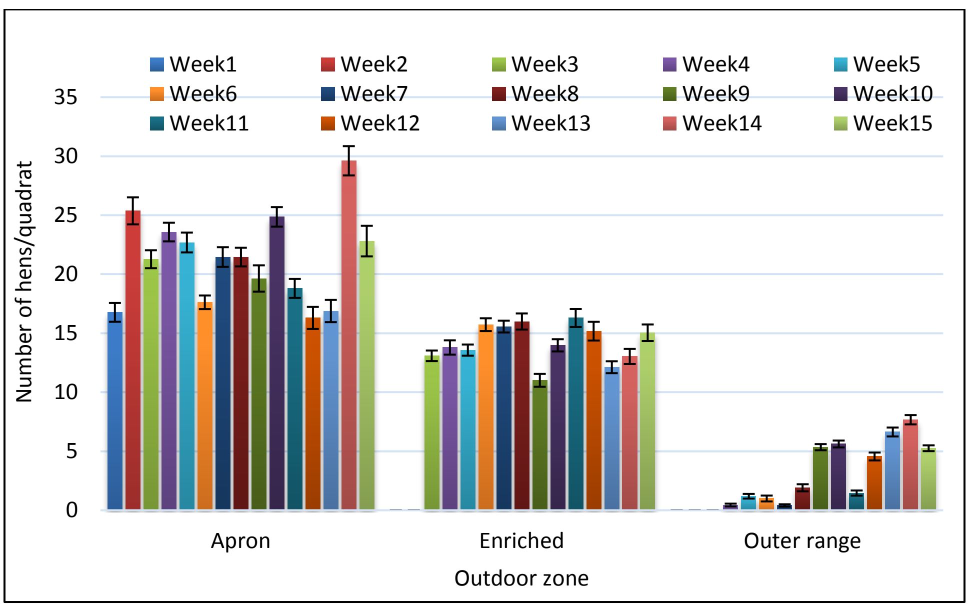


Figure 7.12 Mean (±SEM) number of hens per quadrat in all the outdoor zones during the 15 weeks of outdoor access. The hens used the apron most, least of the outer range with enriched zone at the intermediate for all weeks of access. The hens did not use the enriched and outer range zones during the first 2 weeks of outdoor access.

Effect of time of the day on the number of hens in the range

Time of the day had a significant effect on the number of hens found in the three areas of the range. This was shown by the two-way interaction between zone and time of the day ($F_{8,8939} = 7.364$, $p < 0.001$) which indicated that the number of hens in the three outdoor zones varied throughout the day and likewise, the number of hens outside the shed at different times of the day varied from one outdoor zone to another. The mean difference in the number of hens per quadrat between the time periods was significant in the apron ($F_{4,2995} = 5.595$, $p < 0.001$) and the outer range ($F_{4,2995} = 11.907$, $p < 0.001$) zones but was not in the enriched area ($F_{4,2995} = 2.160$, $p < 0.071$). This means that range use varied significantly between different time periods in the apron and outer range areas but not in the enriched zone. The use of apron and enriched zones peaked in the morning but no variations was seen in the use of the enriched zone through the day (Figure 7.15). The mean difference in the number of hens between the three outdoor zones was significant during the 9am ($F_{2,1797} = 557.785$, $p < 0.001$), 10am ($F_{2,1797} = 611.726$, $p < 0.001$), 11am ($F_{2,1797} = 571.514$, $p < 0.001$), 1pm ($F_{2,1797} = 495.232$, $p < 0.001$) and 2pm ($F_{2,1797} = 441.488$, $p < 0.001$) periods, and this further suggested that the hens were more likely to use the apron compared to the enriched and outer range zones, and also more likely to use the enriched area compared to the outer range zone at any time of the day (Figure 7.13).

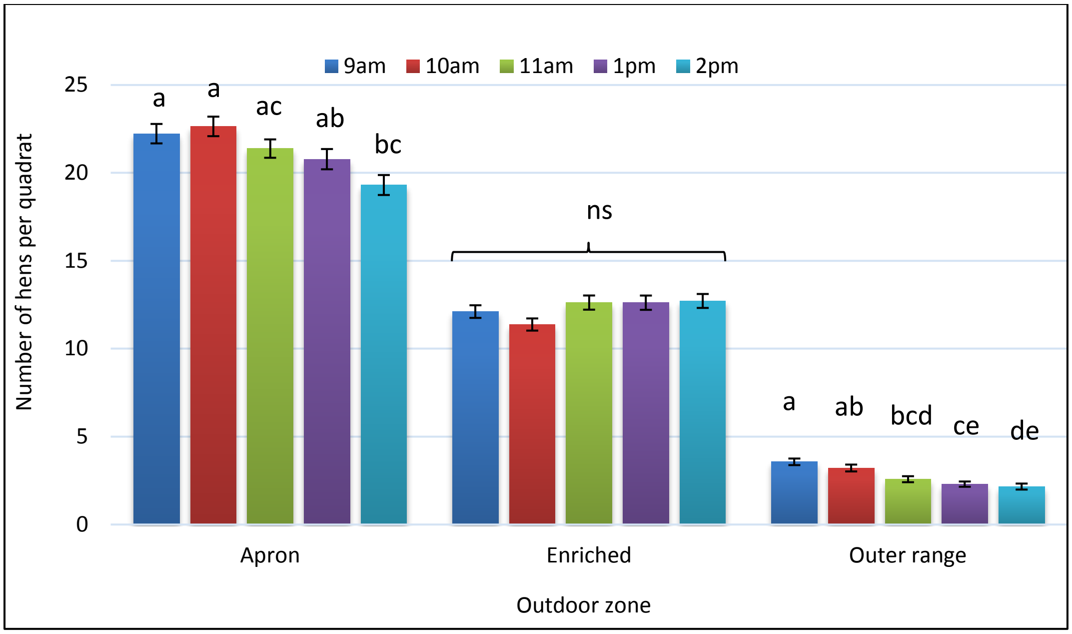


Figure 7.13 Mean (±SEM) number of hens between the time periods in all the outdoor zones. The hens used the apron most, least of the outer range with enriched zone at the intermediate at all times. The use of apron and outer range was greatest in the morning and decreased through the day but the number of hens in the enriched zone did not change during the day. [a,b,c,d,e] Means that different times with different superscripts are significantly different ($p < 0.001$). [ns] Means that there was no significant difference between times ($p > 0.05$).

Effect of temperature, relative humidity and wind speed on the number of hens in the range

The temperature, RH and wind speed varied during this study and the changes was in line with the seasonal changes. The mean values of the weather variables recorded during the study are, temperature, 18. 59 ± 0.048 ^{o}C, ranging from 9.10 to 28.80 ^{o}C); RH (70.71 ± 0.114 %, ranging from 44.0 to 90.0 %) and the wind speed (3.27 ± 0.017 m/s, range from 0.0 to 9.50 m/s). Temperature ($F_{1,8939} = 50.472$, $p < 0.001$, $r = -0.098$) and wind speed ($F_{1,8939} = 6.709$, $p < 0.001$, $r = -0.091$) had significant but low negative effects on the number of hens found in the range which implied that for every increase in the outdoor temperature and wind speed, there was an associated decrease in the number of hens in the range. Relative humidity had no effect on the number of hens in the range ($F_{1,8939}$ = 0.052, p = 0.820, r = 0.091) indicating that during this study, change in the outdoor RH was not associated with an increase or decrease in range use.

Behaviour of the hens in the range

There was no aggressive behaviour recorded during this study and for this reason, it was not included in the GLM analysis. The result of the descriptive statistics showed that the hens in the range were more likely to perform locomotory behaviour followed by foraging, resting and comfort behaviours respectively (Figure 7.14). The hens were more likely to perform resting and comfort behaviours in the apron zone whereas outer range zone was dominated by the foraging and locomotory behaviours.

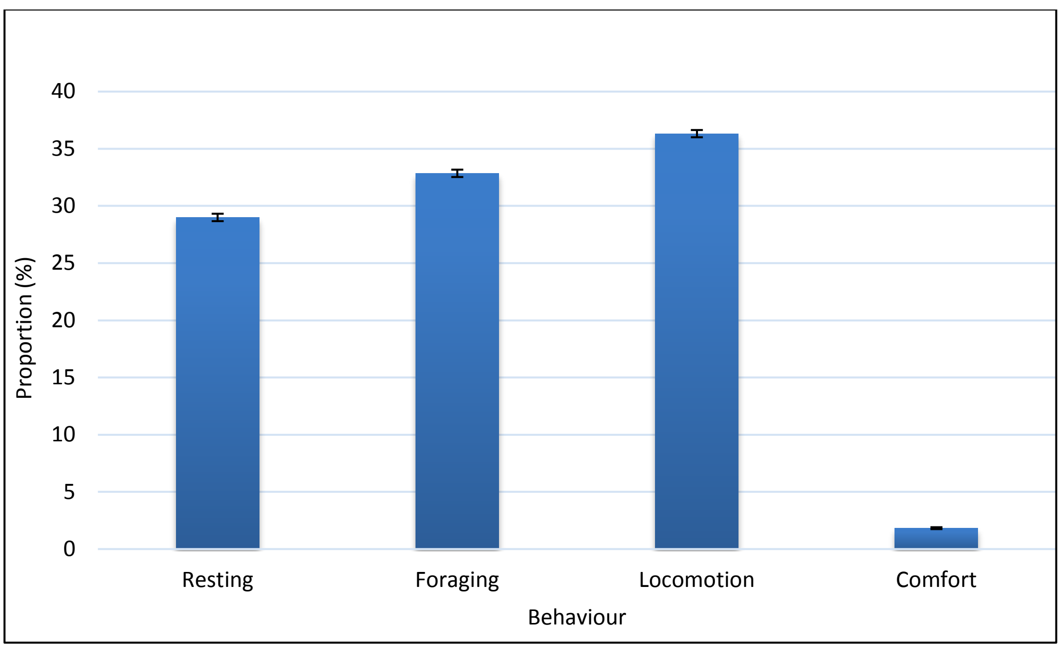


Figure 7.14 Mean proportion (±SEM) of the behaviours of the hens in the range. The hens were more likely to perform locomotory behaviour and least likely to engage in comfort behaviour.

The effect of location of the hens in the range was tested to determine if the behaviour of the hens was from on location to another and the result showed that location had a significant effect on all the behaviours. The mean proportion of resting ($F_{2,6756} = 294.924$, $p < 0.001$), foraging ($F_{2,6752} = 139.676$, $p < 0.001$), locomotory ($F_{2,6756} = 65.906$, $p < 0.001$) and comfort ($F_{2,6756} = 62.940$, $p < 0.001$) behaviours differed significantly between the apron, enriched and outer range zones. The results of descriptive statistics indicated that resting and comfort behaviours were more likely to occur in the apron zone whereas foraging and locomotory behaviours were recorded most in the outer range area with the behaviour proportions being intermediate in the enriched area (Figure 7.15).

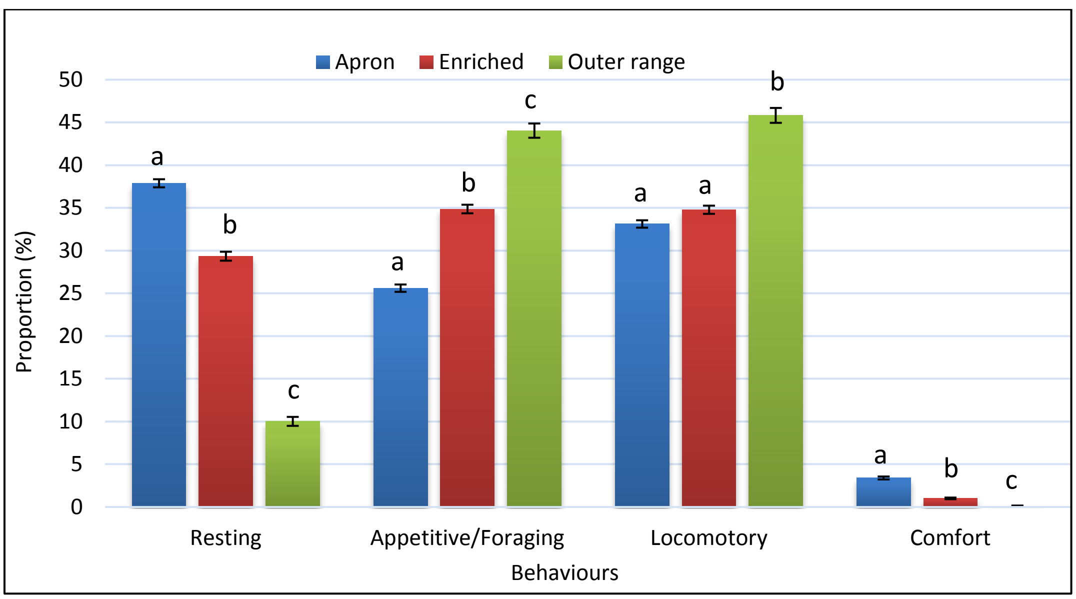


Figure 7.15 Mean proportion (±SEM) of resting, foraging, locomotory and comfort behaviours recorded in the apron, enriched and outer range zones. Resting and comfort behaviours occurred most in the apron zone whereas the outer range area was dominated by foraging and locomotory activities. ^{a,b,c} Means that difference between zones with different superscripts are significantly different ($p < 0.001$).

Effect of time of the day on the behaviour of the hens

The influence of different times of the day on the occurrence of the behaviours was explored to determine if the likelihood of the hens to perform the behaviours in different outdoor locations varied throughout the day. The results showed that time of the day had a significant effect on the proportion of foraging behaviour ($F_{4,6752} = 4.424$, $p < 0.05$, but no effect of time period was detected in the proportion of resting ($F_{4,6741} = 1.164$, $p = 0.325$), locomotory ($F_{4,6749} = 1.884$, $p = 0.110$) and comfort ($F_{4,6741} = 0.612$, $p = 0.654$) behaviours. This results suggested that while the proportion of resting, locomotory and comfort behaviours did not change during the course of the day, the hens were least likely to engage in feeding/foraging behaviour during the earlier hours of the day i.e. at 9am and 10 am, but there was an increase in the proportion of feeding/foraging behaviour between 11am and 2pm (Figure 7.16).

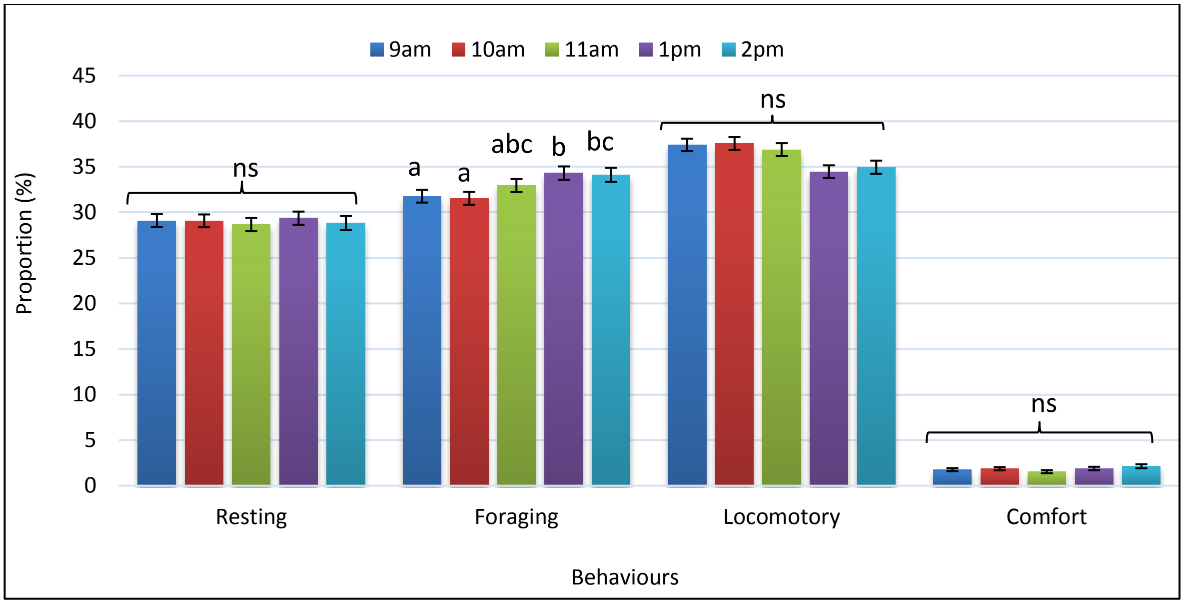


Figure 7.16 Mean proportion (±SEM) of resting, foraging, locomotory and comfort behaviours of the hens at different times of the day. The mean proportion of foraging behavior differed significantly between time periods whereas resting, locomotory and comfort behaviours did not change through the day. [a,b,c] Means that time periods with different superscripts are significantly different ($p < 0.05$). [ns] Means of time periods are not significantly different ($p > 0.05$).

Effect of week of access on the behaviour of the hens

The effect of week of access on the behaviour of the hens in the range was tested to determine if the hens showed any weekly variations in their activity patterns within and between the three outdoor zones and the results showed that week of outdoor access had a significant effect on the proportion of all the behaviours recorded in the range i.e. resting ($F_{24,6756} = 3.848$, $p < 0.001$), foraging ($F_{24,6752} = 4.795$, $p < 0.001$), locomotory ($F_{24,6756} = 4.852$, $p < 0.001$) and comfort ($F_{24,6756} = 3.110$, $p < 0.001$). This interaction indicated that the mean proportion resting, feeding/foraging, locomotion and comfort behaviours varied within and between the three outdoor locations. A detailed table of the F-values and P-values for all the behaviours is presented below (Table 7.0). The hens used only the apron strip in the first two weeks of range access and the apron data could not be compared with the other zones for the first two weeks, hence the *post hoc* tests were carried out from the third week of range access.

The proportion of resting behaviour recorded outdoors differed significantly between weeks of outdoor access in the apron ($F_{14,2828} = 12.792$, $p < 0.001$), enriched ($F_{14,2828} = 4.855$, $p < 0.001$) and outer range ($F_{14,2828} = 4.760$, $p < 0.001$) zones with its occurrence was found to decrease in the apron zone but increased in the enriched and outer range zones as the weeks of range access progressed. Also, the mean proportion of resting behaviour was found to differ significantly between the three outdoor zones from week 3 through to week 15 of outdoor access (Table 7.17) with its occurrence found to be greatest in the apron, followed by the enriched and outer range zones respectively. This implied that the hens in the apron were more likely to engage in resting behaviour compared to their counterparts in the other parts of the range.

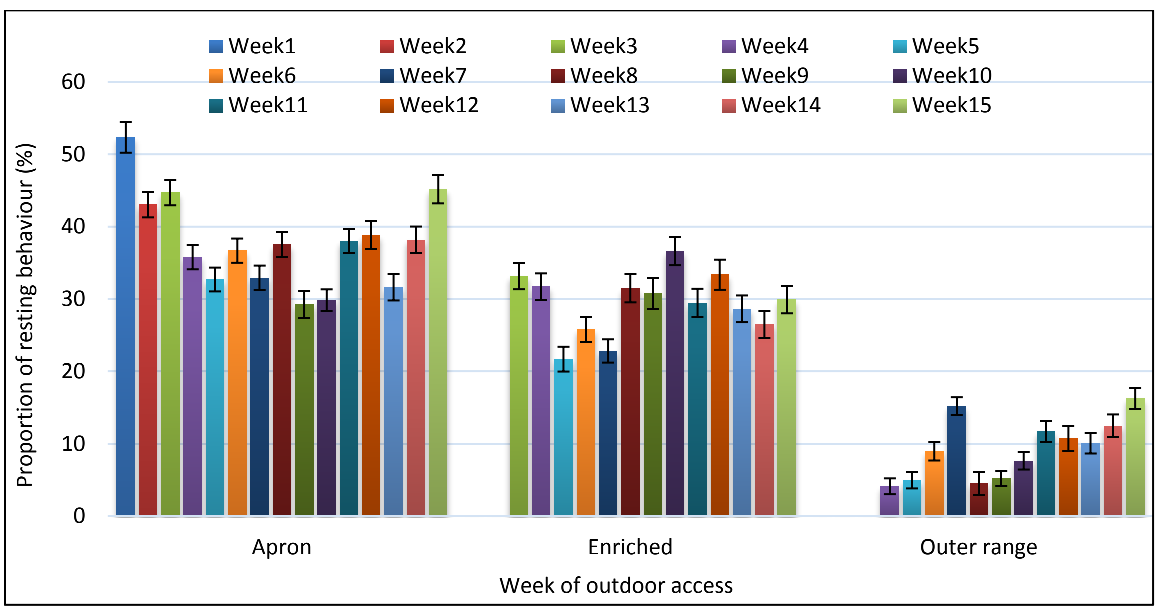


Figure 7.17 Mean proportion (±SEM) of resting behaviour for all the weeks of outdoor access. Resting behaviour was greatest in the apron and least in the outer range. There was decrease in its occurrence in the apron but increased in the enriched and outer range zones during the weeks of access.

The proportion of foraging behaviour differed significantly between the weeks of range access in the apron ($F_{14,2828} = 8.250$, $p < 0.001$), enriched ($F_{14,2828} = 9.133$, $p < 0.001$) and outer range ($F_{14,2828} = 6.163$, $p < 0.001$) zones, foraging behaviour found to decrease in the apron but increased in the enriched and outer range zones during the study period (Table 7.0). The mean proportion of foraging behaviour was found to differ significantly between the apron, enriched and outer range areas in week 3 through to week 15 of range access (Table 7.0) with its greatest occurrence recorded in the outer range, followed by the enriched and apron zones respectively (Figure 7.18).

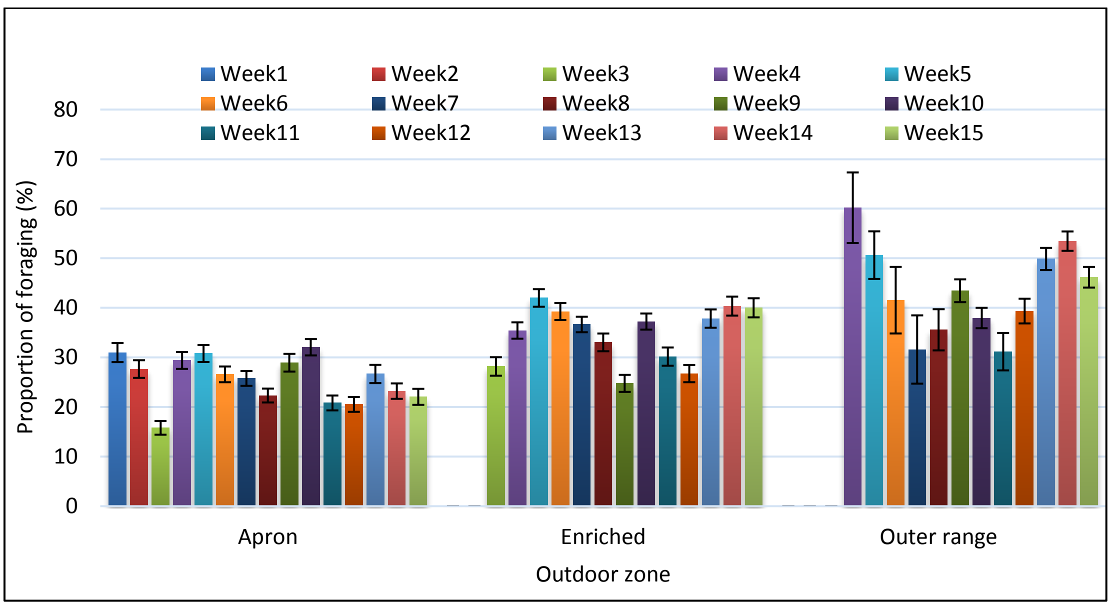


Figure 7.18 Mean proportion (±SEM) of foraging behaviour for all the weeks of outdoor access. The foraging behaviour was least in the apron and increased as the distance from the shed increased.

The proportion of locomotion recorded in the range differed significantly between the weeks of range access in the apron ($F_{14,2828} = 15.958$, $p < 0.001$), enriched ($F_{14,2828} = 7.027$, $p < 0.001$) and outer range ($F_{14,2828} = 8.789$, $p < 0.001$) zones with its occurrence found to increase in all the outdoor zones as the week of range access increased (Figure 7.19). The mean proportion of locomotion also differed significantly between the three outdoor zones in most weeks of outdoor access with the hens in the outer range found to perform more movements compared to the enriched and apron users (Figure 7.19).

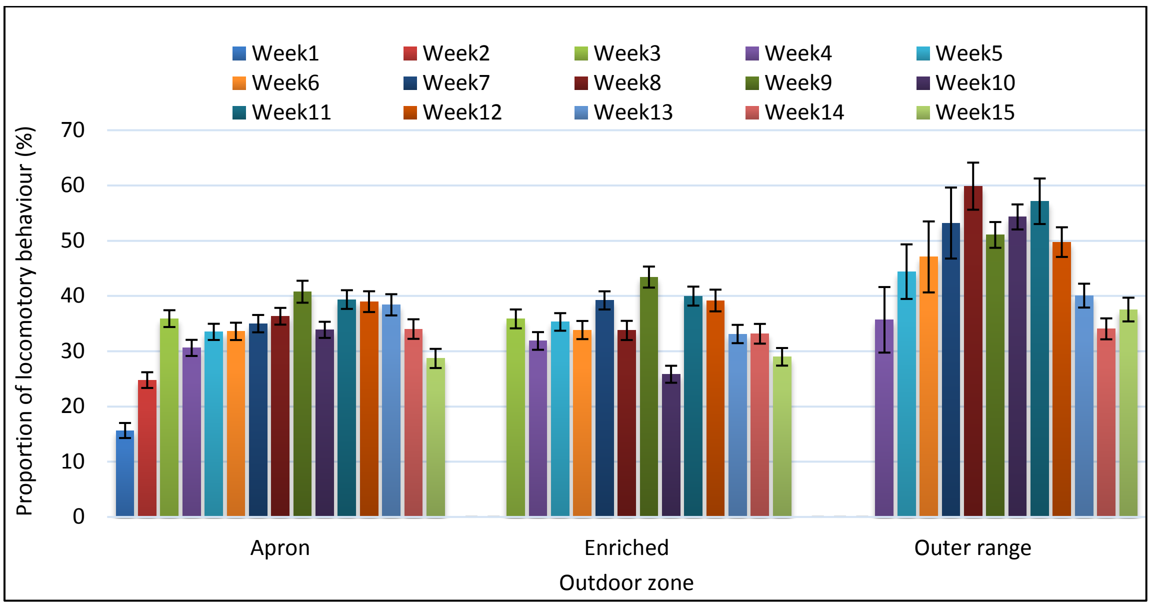


Figure 7.19 Mean proportion (±SEM) of locomotory behaviour for all the weeks of outdoor access. The hens moved most in the outer range and least in the apron and increased as the week of access increased in all the outdoor zones.

Comfort behaviour also showed similar pattern of occurrence as the resting behaviour with the difference in its occurrence found to differ significantly between weeks of outdoor access in the apron ($F_{14,2828} = 4.899$, $p < 0.001$), enriched ($F_{14,2828} = 4.953$, $p < 0.001$) and outer range ($F_{14,2828} = 4.170$, $p < 0.001$) zones. The results suggested that there was a decrease in the proportion of comfort behaviour recorded in all the outdoor zones with repeated weekly range access (Figure 7.22). The proportion of comfort behaviour also differed significantly between the apron, enriched and outer range zones in most of the weeks of outdoor access. This implied that the hens performed more comfort behaviour in the apron and least in the outer range zone with enriched area at the intermediate for all the weeks of range access (Figure 7.20).

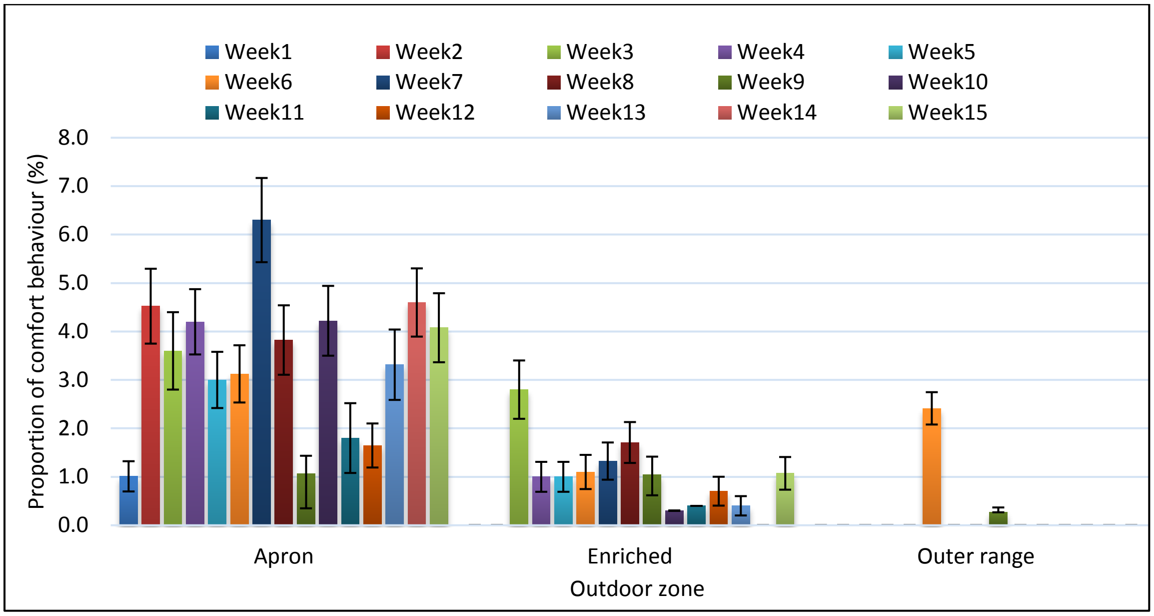


Figure 7.20 Mean proportion (±SEM) of comfort behaviour recorded in the apron, enriched and outer range zones for weeks of outdoor access. Comfort behaviour occurred least in the outer range and most in the apron zone and decreased through the 15-week study period in all the zones.

Week	Resting		Foraging		Locomotion		Comfort	
	F-value	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**	**F-value**	**P-value**
Week 3	20.812	<0.001	28.268	<0.001	0.000	0.983	0.639	0.424
Week 4	13.171	<0.001	14.069	<0.001	0.508	0.602	10.735	<0.001
Week 5	28.071	<0.001	15.530	<0.001	3.799	0.023	6.871	0.001
Week 6	22.584	<0.001	15.164	<0.001	4.305	0.014	4.075	0.018
Week 7	12.400	<0.001	11.676	<0.001	6.306	0.002	16.541	<0.001
Week 8	44.529	<0.001	12.414	<0.001	28.587	<0.001	7.473	0.001
Week 9	77.324	<0.001	25.374	<0.001	6.465	0.002	2.254	0.106
Week 10	91.839	<0.001	3.240	0.040	67.076	<0.001	28.954	<0.001
Week 11	28.611	<0.001	8.384	<0.001	13.926	<0.001	6.079	0.002
Week 12	51.860	<0.001	23.233	<0.001	7.507	0.001	4.881	0.008
Week 13	45.641	<0.001	33.016	<0.001	3.731	0.025	18.404	<0.001
Week 14	53.602	<0.001	67.853	<0.001	0.077	0.926	45.521	<0.001
Week 15	64.453	<0.001	40.314	<0.001	7.499	0.001	24.089	<0.001

Table 7.0 Showing the F-values and P-values of the interactions between zone and week. The behaviours were found to largely differ significantly between the weeks of range access in all the outdoor zones.

Summary of discussions

Free-range laying hens do not normally have access to the range until laying is established and this delay has the potential to limit range use especially in the early period of range access. This delayed range access is likely to result in a reduction in the benefits derivable from range use in these hens e.g. reduced fitness, less opportunities to roam and express most natural behaviours. The ability of the hens to leave the shed in the early days of range access may be associated with the fear of their new outdoor environment (Grigor *et al*. 1995a; 1995b) that they did not access during the rearing period. Laying hens have been reported to show increased tendency to use the range when they became familiar with the environment as a result of the repeated use (Grigor *et al*. 1995a; 1995b; Abouelezz *et al*. 2014) and as they get older (Albentosa *et al*. 2003, Gilani *et al*. 2014). The result of the current study is in agreement with the findings of the six flock study presented in the chapter 4 of this thesis, and showed that the farther a location is from the shed, the less the likelihood for the hens to utilize it e.g. the hens were found to aggregate most in the apron followed by the enriched and outer range zones. This results further suggested that the hens had a stronger preference for the immediate strips of the shed i.e. apron zone, compared to the distant areas i.e. enriched and outer range zones (e.g. Nicol *et al*. 2003; Nagle and Glatz, 2012). Repeated, weekly range access appeared to be associated with increased familiarization of the range as the use of range was found to increase as the study period progressed. This increase in the outdoor use was also associated with increase in the activity level of the hens in the range. Range use was also influenced by the time of the day with greatest number of hens recorded outdoors in the morning followed by a decreased in outdoor use as the day progressed.

Influence of outdoor location on the use of range

There is evidence that hen distribution in the range depended on the location where the observation was carried out with the hens found to prefer the apron zone compared to the enriched and outer range zones and the enriched zone was also preferred to the outer range area. The number of hens in the range dropped as the distance increased from the shed (Keeling *et al*. 1988; Nicol *et al*. 2003; Nagle and Glatz, 2012).

The greater use of apron by the hens could be because apron zone was the part of the range closest to the shed and offered them quicker and easier access to the feed and water in the shed. This is because the apron users have the least distance to travel before accessing the shed in comparison to their counterparts in the farther range areas. The hens close to the shed are more likely to secure feeding spots in the shed (Bubier and Bradshaw, 1998) compared to their counterparts in the enriched and outer range areas and this suggested that the relative attractiveness of the shed may have discouraged the hens from using the distant parts of the range.

The trees found in the enriched zone did not provide sufficient cover for the hens and the may have chosen the location that appeared to have the potential to offer them greater safety (Nicol *et al*. 2009; Browne *et al*. 2010). Laying hens have been found to prefer locations where their level is low (Nicol *et al*. 2009; Browne *et al*. 2010) suggesting that they may have experienced the reduced fear level in the apron zone compared to the other areas. Hartcher *et al*. (2015) studied the relationship between range use and fearfulness in laying hens and reported a negative relationship between fearfulness and range use in the ranging hens. They argued that handling activities of laying hens every 4 to 6 weeks and the daily human access to the experimental pens have resulted in reduced fear level in the hens leading to an increase in the number of hens found outside the shed. The hens may have adopted anti-predator strategy (Nagle and Glatz *et al*. 2012) as they appeared to have preferred safety e.g. they choose locations that offered greater chances of survival from predator attacks.

Provision of additional enrichment resources e.g. tree covers, shelterbelts, artificial cover in the range was found to encourage more hens to use the range (Weeks and Nicol, 2006; Nicol *et al*. 2003; Nagle and Glatz, 2012; Zeltner and Hirt, 2008a; Hegelund *et al*. 2005; Harlander-Matauschek *et al*. 2006). These resources provide protection for the hens against inclement weather conditions and predators and also result in reduced fearfulness in laying hens (Collias, 1987). The tree covers found in the enriched zone of the current study did not provide enough cover and may not have attracted or encouraged the hens to range away from the apron zone. The hens in the current study were housed in a large shed and had to encounter many unfamiliar individuals (especially around the pop hole area) before accessing the range (Grigor *et al*. 1995c) and based on this they are likely to spend longer time travelling to the range or may not reach the range at all. Grigor *et al*. (1995b) designed a two-experimental study that investigated the effects of social rank and novelty of outdoor area on the emergence and dispersal behaviour of laying hens. In their first experiment, hens were trained to walk from an empty cage (cage 1) through a runway into a larger cage (cage 2) containing food, water and shavings. Another cage (cage 3) was designed to protrude unto the runway and contained either a dominant, subordinate, unfamiliar or no hen while a test hen walked from cage 1 to cage 2. They found that the hens spent longer time traveling from cage 1 to cage 2 when cage 3 was occupied by unfamiliar bird. They designed the second experiment which involved a further increase in the number of the middle cages (cage 3) protruding unto the runway to four and placed unfamiliar birds in all of them to test the effect of the number of unfamiliar individuals on the movement of the tested hens. They found that the passage time of the hens increased as the number of unfamiliar birds encountered in the runway increased. In the current study, the apron zone has greatest number of hens and the report of Grigor *et al*. (1995b) above suggested that the hens may have been discouraged from moving through the pop holes and the apron zone to reach the enriched and outer range zones because they had to encounter many unfamiliar hens on their way.

Effect of week of access on the use of range

Effect of the week of range access on the use of range was tested and the results indicated that range use was least during the earlier weeks of range access e.g. weeks 1 and 2, but increased with repeated and continuous range access at the time of the study. Week of range access interacted significantly with zone and this suggested that during this study, the weekly use of range depended on the outdoor location (zone). The hens used the closest area of the range during the early weeks of access (weeks 1 and 2) before they moved on to the enriched and outer range zones from weeks 3 and 4 respectively. All the outdoor zones were used by the hens between from the 4th week through to the 15th week of range access and there were more hens in the apron compared to the enriched and outer range zones between weeks 4 and 15.

The hens used in the current study were not allowed outdoor access prior to the initial range access at 20 weeks of age and being that they spent this long time in the shed, they appeared to be reluctant to emerge from the shed or even venture into the far range (e.g. Grigor *et al*. 1995a). Range use by laying hens have been widely researched and previous experience have been reported to be influence the ability of the hens to use the range (Grigor, 1993; Grigor *et al*. 1995a). Increased fear responses have been reported in laying hens exposed to novel environments e.g. outdoor run (Grigor *et al*. 1995b), but declined when they were allowed repeated access to the same environment (Grigor, 1993) and as they aged (Gilani *et al*. 2014; Albentosa *et al*. 2003). Icken *et al*. (2008) studied the ranging behaviour and laying performance of 272 Lohmann Silver strain of laying hens and reported that 26% of the hens visited winter the garden at the start of the recording period compared to 60% of outdoor visit between laying periods 10 to 12. Their results implied that the increase in the use of outdoor area was associated with increased duration of their stay in the garden.

Grigor *et al*. (1995a) investigated the impact of regular handling and exposure to an outside area on subsequent fearfulness and dispersal of domestic hens in a three-experiment study and found that previous experience in the range was associated with reduction in the fear level of both immature and adult hens whereas handling alone had no effect on these parameters. They assessed the effect of three treatments i.e. (T1) no handling plus no outdoor experience (T2) regular handling plus no outdoor experience (T3) regular handling plus outdoor experience on the fear levels, readiness to emerge from a familiar box and if the relationship between the outdoor experience and fear level occurred in older free-range birds. They found that the hens with previous outdoor experience emerged from the test boxes quicker and were often found to travel far from the boxes. They suggested that regular range experience during rearing stage resulted in the greater readiness of the birds to use the range at adult age. They attributed the increases readiness to the increased environmental familiarization that resulted from the repeated use same environment. It was possible that the increased use of range by the hens in the current study was also influenced by the increased environmental familiarization as reported by Grigor *et al*. (1995a).

Effect of time of the day on the use of range

The hens were found to show variations in range use between different times of the day e.g. there were more hens in the range in the morning compared to the afternoon with least number of hens recorded in the range. The number of hens out of the shed at different times of the day depended on the outdoor zone with more hens found in the apron and outer range zones in the morning compared to the afternoon periods whereas the use of enriched zone did not vary through the day. The findings of this study was in line with many studies that reported greater outdoor use by laying hens in the morning compared to later times of the day (Mahboub *et al.* 2004; Hegelund *et al*. 2005; Nagle and Glatz, 2012; Abouelezz *et al.* 2014). Hegelund *et al*. (2005) investigated the use of range in 37 organic laying flocks in Denmark and reported that time of the day had a negative effect on the number of hens using in the range (-0.3438 ± 0.2252). with more hens found outdoors in the morning and least in the evening. Abouelezz *et al*. (2014) studied the use of outdoor range and activities of Rhode Island Red hens grazing on natural vegetation in the tropics and found that the highest average use of the range was recorded during the early hours of the day compared to the mid-day and late hours of the day. They reported that majority of the hens used the range between 8 to 11am (46.1%) followed by 2 to 5pm (39.3%) and 11am to 2pm (36.2%). Also, Nagle and Glatz (2012) reported similar daily pattern of range use in a study that explored the use of outdoor area by free-range laying hens when the outdoor was enriched with forage, shade and shelterbelts compared to no enrichment group (control). They found that when forage was provided to the control birds, there were more hens outside the shed in the morning than in the afternoon. They also reported that the hens that were provided with shelterbelts used the paddock more in the morning compared to the afternoon period although this trend was reversed with increase in the environmental temperature. Mahboub *et al.* (2004) studied the movement of free-range laying hens between the house and the outdoor areas (winter garden and grassland linked with passages) and the time they spent in each area. They found that the hens spent maximum time in the grassland in the morning (5 to 7am) and in the afternoon (12 to 3pm) although there was a general decrease in range use during the day. They also found that the hens in the winter garden spent more time outside in the morning than in the afternoon. Their results further suggested that the hens did not only use the range more but also spend more time outdoors in the morning.

Effect of temperature, relative humidity and wind speed on the use of range

The use of range was influenced by the weather variables recorded during the study, with temperature and wind speed found to have significant negative effects on the number of hens in the range whereas RH had no effect on range use. The above results suggested that the number of hens in the range decreased with increased temperature and wind speed but changes in the RH did not affect outdoor use. The effect of weather conditions on range use have been widely studied (Nicol *et al*. 2003, Hegelund *et al.* 2002; 2005; Richards *et al*. 2011; 2012; Nagle and Glatz, 2012; Gilani *et al*. 2014) and mixed outcome was reported.

The report of Gilani *et al*. (2014) is in line with the current study as they found that more hens ranged on cooler days, lower rainfall, lower outdoor humidity levels and when artificial structures were provided in the range. They investigated the factors affecting ranging behaviour 33 flocks of young (during rearing) and adult (during lay) laying hens with or without range access and concluded that the provision of cover in the range attracted the hens away from the shed through its protective properties and reduced the effects of bad weather (temperature, rainfall and RH) on the hens.

However, other studies reported different effects of the weather variable on pop hole use (Hegelund *et al*. 2005; Richards *et al.* 2011; Richards *et al.* 2012). Richards *et al.* (2011) studied the pop hole use in free-range laying hens during an entire production cycle of the hens and found that environmental temperature had the largest effect on the pop hole activity of the hens with every degree Celsius increase in temperature found to result in a 0.0418 increase in pop hole use. They also found that wind speed and daily rainfall had negative impact on pop hole usage with increase in wind speed and rain fall was associated with a reduction in pop hole usage. Richards *et al*. (2012) also used the RFID technology to study pop hole use of laying hens with keel bone fracture. They also found similar effects of daily temperature, rainfall, wind speed and wind direction as Richards *et al.* (2011). They found that temperature had positive effect on pop hole use with increase in the environmental temperature found to be associated with a rise in pop hole use by the hens and also that pop hole usage decreased as the wind speed increased and as the wind blew into the pop holes. The hens used by Richards *et al*. (2011) and Richards *et al*. (2012) were individually identified with (RFID) technology to monitor their movement in and out of the pop holes but there was no detail on whether the hens continued into the range or not. However, they argued that the degree of pop hole use in laying hens was a potential indicator of the mobility and intention of the hens to access the range. A more detailed study will be beneficial to establish whether the pop hole users are also range users and to also know if environmental factors have similar effect on their usages. Also, the study of Hegelund *et al*. (2005) did not agree with the results of the current study. They explored the effect of climatic factors, flock size, age and artificial cover on the use of range in 5 farms of commercial organic laying hens in Denmark and reported that increase in wind speed resulted in a decline in range use and that temperature had a parabolic relationship with the number of hens found in the range with range use reported to increase up to 17^{o}C and then decreased with further increase in the environmental temperature.

Nicol *et al*. (2003) investigated the risk factors for feather pecking in a matched concurrent case-control study of commercial free-range laying hens by carrying out interviews alongside direct observations of the hens in the shed and the range. They found that the hens utilized the range more when it was calm and dull whereas the number of hens found outdoors declined in wet, cold and sunny conditions. Their reports suggested that environmental temperature had a positive impact on the use of range, with the hens more likely to use the range in warmer conditions as opposed to the negative effect of temperature on range use reported in the current study. Similarly, Nagle and Glatz, (2012) tested the effect of enrichment resources (forage, shade and shelterbelts) on the use of range by free-range laying hens and found that the number of hens in the range increased as the environmental temperature increased. They concluded that the provision of pasture, shaded areas, hay bales, shelterbelts or shade cloth shelters in the range area attracted more hens into the range and there are chances that the enrichment resources had counteracted the negative impacts of the temperature on the hens so the hens were able to utilize the shades and shelterbelts without needing to move back into the shed.

It was also possible that the outcome of the current study and other studies presented above differed because of the presence of other confounding factors e.g. flock size, stocking density and age which may have masked the effect of one or more of the weather variables in the studies thereby making the interpretation of results from different even more difficult (Keeling *et al*. 1988).

Behaviour of the hens and its distribution in the range

The descriptive statistics showed that locomotion was the most recorded behaviour in the range, followed by foraging, resting and comfort behaviours respectively and this implied that the hens that used the range were more likely to move compared to other activities. Evidence also showed that the location of the hens in the range had a significant effect on their behaviours with the hens more likely to engage in resting and comfort behaviours in the apron zone compared to their counterparts in the enriched and outer range areas and that the hens in the outer range were more likely to forage. This study provided a good estimate of the likelihood of the behaviours occurring or not occurring in the three outdoor areas but did not give an overview of whether more hens in different outdoor locations had behaved differently.

The outdoor locations were not only differentiated by their relative distances away from the shed but also by the type of enrichment resources found in them. The apron zone (located nearer to the shed) had no enrichments and preceded the enriched zone where all the enrichments resources e.g. trees, artificial shades were found. Also the outer range was the farthest part of the range and was made up of large open grassland with no enrichments and constituted the largest area of the range. It was likely that the differences in the proportion of the behaviours recorded between the three outdoor locations in the current study was a result of the variations in the resources and/or space availability to the hens in the different areas (Carmichael *et al*. 1999; Collins *et al*. 2011; Abouelezz *et al*. 2014). Collins *et al*. (2011) investigated the effects of environmental resources and social dynamics on clustering behaviour and activity synchrony in laying hens and found that hens in all the tested environments (wire floor, shavings and perches, peat, nest box and shavings) clustered and concluded that clustering behaviour was caused by resource use and not social cohesion between the individual hens. Laying hens have been reported to show variations in their daily behavioural patterns (Dawkins, 1989; Collias and Collias, 1967) and environmental resources was also found to influence their behaviours (Abrahamson *et al*. 1996; Appleby and Hughes, 1991; Hansen, 1994; Collins *et al*. 2011; Carmichael *et al*. 1999). The use of outdoor range and activities of Rhode Island Red layer hens kept on natural vegetation in the tropics have been investigated (Abouelezz *et al*. 2014) and there was evidence that behaviour of the hens (in nature and proportion) was triggered by the resource differences between locations the hens found spent substantial amount of time performing laying (5.9%), eating (19.3%), drinking (7.3%), exploring (13.4%), resting (16.0%), roaming (15.6%), standing (14.4%) and primping (8.1%) behaviours in the shed compared to their ranging counterparts that engaged in foraging (11.4%), exploring (8.62%) and roaming (6.1%), standing (3.5%), primping (5.6%) and resting (5.4%) behaviours. The hens in the current study showed an evidence of increased foraging behaviour in the outer range zone (largely made up of grasses) compared to the hens in other outdoor locations probably because of there were more forages which had potentially increased their chances foraging. Also, locomotion occurred least in the apron zone of the current study but increased as the distance from the shed increased and one of the possible explanations to this trend was the differences in the stocking density between the three outdoor zones. The stocking density (hens/quadrat) dropped with increased distance from the shed and the hens had greater space between them which appeared to have resulted in greater movements in distant outdoor zones. This is in line with the work of Carmichael *et al*. (1999) which reported that laying hens performed less movement, foraging and dust-bathing behaviours in crowded whereas standing behaviour increased with crowding. Their findings further suggested that the greater resting behaviour recorded in the apron region of the current study could be associated with the high number of hens found in this zone. In the current study, comfort behaviour occurred most in the apron zone where stocking density was greatest and this agreed with the work of Zimmerman *et al*. (2006) where greater comfort behaviour was recorded in large flocks with high stocking density of 12 birds/m^2.

It was also possible that the hens in each of the outdoor location had influenced the behaviour of their conspecifics socially (Nicol, 1989; Nicol, 1995; Nicol, 2006) with chances that the dominant behaviours in each outdoor area was elicited by the available resources (Collins *et al*. 2011) and copied by other hens in the flock (Nicol, 1989; Nicol, 1995; Nicol, 2006) through social influences or transmission (Nicol, 1989; Nicol, 1995). Nicol (1989) examined the social influences of comfort behaviour in laying hens and found that tail wagging behaviour increased when pen mates were visible and also that body shaking, and preening behaviours increased when pen mates were in close proximity. Nicol (2006) reviewed the learning mechanisms in animals and argued that domestic chickens have the ability to learn socially from others e.g. chick from hen, chick from chick, juvenile from juvenile and hen from hen. Another review carried out by Nicol (1995) examined the social transmission of information and behaviour in animals (pigs, cattle, cats, sheep, dogs, chickens and horses) and reported that behavioural influence and subsequent learning in animals can take place through visual, olfactory and auditory cues derived from social contacts which implied that laying hens in the current study may have engage in or learnt the behaviours that they saw others perform. The effect of social influence/transmission on the behaviour of laying hens is well documented (Nicol, 1989; Nicol, 1995; Grigor *et al*. 1995a, 1995b; Nicol, 2006) and there are potential issues with the findings of the current study. This is based on the fact that the current study observed the behaviour of few individuals (5 hens) in a relatively small area (10 x 10m quadrat) of each outdoor zone. It is important to note that while the current study had provided a good estimate of the likelihood of behaviours occurring most or least in specific locations, there are chances that some of the behaviours may have been over-represented due to social factors. This may be the case of locations where greater social influence/transmission had occurred thus resulting in the more hens performing similar behaviours.

Effect of time of the day on the behaviour of the hens

Behaviour of the hens in the current study was significantly influenced by the time of the day and this implied that there were daily variations in the proportion of the behaviours of the ranging hens at the time of the study. The daily variation was seen only in the proportion of foraging behaviour but not in the locomotory, resting and comfort behaviours which was had similar proportion throughout the day. The hens were less likely to engage in foraging in the early hours of the day but this behaviour increased through the day.

Scientists have reported that the behaviour of chickens e.g. roosting, vary during the day (Appleby *et al*. 1993; Olsson and Keeling, 2000; Abouelezz *et al*. 2014) although the reports did not agree with that of the current study. Abouelezz *et al*. (2014) studied the use of outdoor range and activities of laying hens and reported daily changes in the activity of both outdoor and indoor raised hens. They found that the hens found in the range performed more foraging, exploring, roaming, and primping in the early hours of the day (between 8am and 11am) compared to midday (11am to 2pm) and late hour (2pm to 5pm) periods. They also reported that resting and drinking behaviours almost doubled during the midday and late hours compared to the early hours. Appleby *et al*. (1993) investigated the nesting, dust bathing and perching behaviour of ISA Brown hybrid of laying hens in cages and found that they showed daily variations in dust bathing behaviour. They reported that the occurrence of dust bathing behaviour was greatest in the afternoon and in a single bout of about 5 minutes.

The studies presented above showed that the behaviour of hens can vary during the day but the direction of the change may be difficult to determine as it is likely to depend on other factors e.g. climate, proportion of outdoor use. In the current study, the behaviour study was carried out in a temperate country compared to the work of Abouelezz *et al*. (2014) carried out in the tropics where temperature appeared to have peaked at midday and late hours and during this period the hens are more likely to rest while increasing their water intake to enable them regulate their body temperature. The difference in the climatic conditions may have contributed to the effect of time of the day on foraging behaviour.

Effect of week of access on the behaviour of the hens

Week of outdoor access was found to influence all the behaviours recorded in the range. The proportion of resting and comfort behaviours decreased over the study period whereas foraging and locomotory behaviours increased during the study period. The hens were found to use only the apron zone during the first two weeks of range access but showed an increase in the entire outdoor use, including the distant parts of the range. The increase in the use the distant outdoor zones meant that the individual hens had walked greater distances (to reach these areas to access more forages) compared to the earlier weeks. The overall increase in the use of range appeared to have resulted in greater movements and more foraging activities whereas resting and comfort behaviours decreased. Further to this, the enriched and outer range zones had greater roaming spaces than the apron strip and the hens are more likely increase their movements when they have greater space to move but may perform more resting and comfort behaviour when the space is smaller (Rhim, 2014).

In the current study, the week of outdoor access was found to interact with outdoor zone and this indicated that the proportion of the individual behaviours recorded in the range during the study period depended on the location of the hens in the range. The hens performed more resting and comfort behaviours in the apron zone compared to foraging and locomotory behaviours that occurred most in the outer range zone and this pattern appeared to be influenced by the enrichment resources found the different parts of the range (Collins *et al*. 2011; Carmichael *et al*. 1999; Abouelezz *et al*. 2014). It could be that with the repeated use of the range over the weeks of access, the hens had familiarized themselves of all the parts of the range (Grigor, 1993; Grigor *et al*. 1995a) and as a result had increased access to forage substrates that encouraged foraging behaviour.

Conclusions

At the start of this study, the hens were reluctant to use the range and during this period, they did not go beyond the immediate surroundings of the shed. The use of other outdoor areas was found to increase during the study and this progressive increase was associated with the use of the resources in the other parts of the range e.g. access to more foraging substrates resulted in more foraging behaviour recorded with increased weeks of range access. The most preferred part of the range was the immediate vicinity of the shed but preference declined with increased distance from the shed, suggesting that there were differences in the attractiveness of the different areas. Studies have suggested that providing enrichment resources (e.g. covers, hedges, artificial structures) in the range, reducing indoor stocking density, reducing flock size and allowing hens range access during rearing have the potential to improve the use of the range and based on this, the ranging ability of the hens in early lay can be improved by applying these measures. Enrichment on the other hand, is an effective tool in counteracting the negative effects of climatic factors on the use of range by providing protection for the ranging hens.

Chapter 8

General summary

This chapter summarizes the main findings of the single and six flock studies presented in the chapter 4 and chapter 7 of this thesis, with emphasis on the differences and similarities between them in relation to the published scientific evidence. The two studies found similar pattern of range use in the laying hens with indications that the hens preferred to use the immediate surroundings of the shed compared to enriched and range areas (Table 8.0). This showed that the two studies agreed with each other and also with other published studies (e.g. Keeling *et al*. 1988; Nicol *et al*. 2003; Nagle and Glatz, 2012). There was slight difference between quadrat in the two studies, but this difference may have been as a result of the difference between data collection tools used in the two studies (direct observations vs digital camera). The report of the proportion of range use suggested a poor outdoor turn put and that the outdoor environment was less attractive to the hens, resulting in the greater number of hens in the shed. Flock (e.g. size and age of hens), house (e.g. pop hole location) and weather variables (e.g. temperature, RH, wind speed) was found to influence the number of hens in the range in both studies and this is in line with the published evidence (e.g. Bestman and Wagenaar, 2003; Hegelund *et al*. 2005; Gilani *et al*. 2014).

The hens kept in smaller flocks were found to range more compared to their counterparts in large flocks and this poor use of range has been identified as a major risk factor for increased feather pecking and cannibalistic behaviour in laying hens (e.g. Appleby *et al*. 1992; Bubier and Bradshaw 1998; Jones 1997; Nagle and Glatz, 2012). Reduced range use leads to increased indoor stocking density which can in turn result in greater inhibition of movement of other hens into the range (Carmichael *et al*. 1999).

The two studies reported that range use was influenced by the outdoor temperature but the effect was not similar in both cases. The use of range in six flock study was positively associated with increase in temperature whereas there was a negative effect of temperature on the use of range in the single flock study. The variation between the outcomes of the two studies appeared to have resulted in the different temperature values recorded in the two studies. Temperature was reported to have a parabolic effect on the ranging behaviour of commercial organic laying hens with outdoor use reported to increase until 17°C before decreasing (Hegelund *et al*. 2005) and based on this, the hens may have reacted differently in the two studies. The Maximum outdoor temperature recorded during the six-flock study was 17.5°C whereas 28.8°C was recorded in the single flock study. Being that the hens showed greater ranging activity below 17.5°C mark and reduced range use at temperature values beyond 17°C, it was possible that similar effect resulted in the difference between the six flock and the single flock studies. The results of the two main studies of this thesis would be more robust if additional weather measures e.g. rainfall, wind direction, atmospheric pressure, were included. This would have provided additional details on how the use of range, behaviour and NND of the hens may have changed as these weather factors varied in the range.

The weekly pattern of outdoor use from the point of initial range access in the single flock study showed that the hens did not use the enriched and outer range zones immediately after turn out i.e. they utilized only the apron area in the first few weeks of range access before venturing into the enriched and outer range zones. The hens in this study were observed for 15 weeks, implying that they got older as the weeks progressed. Being that range access increased with age, it was likely that similar effect occurred throughout the 15-week study and this indicated that the findings of the two studies presented in this thesis agreed with other studies (e.g. Albentosa *et al*. 2003; Gilani *et al*. 2014) although the outcomes were interpreted in slightly different ways. It was likely that the laying hens had become familiar with the range (Grigor *et al*. 1995a) or had reduced level of fear (Grigor *et al*. 1995b) during the lay period, hence the increase range turn out.

Outdoor zone	**Hens /quadrat in six flock study**	**SEM**	**Hens /quadrat in single flock study**	**SEM**	**Difference between studies**
Apron	30.87	0.44	21.27	0.25	9.60
Enriched	8.97	0.22	12.29	0.17	3.32
Outer range	1.60	0.18	2.76	0.13	1.16

Table 8.0 showing the differences in range use (hens/quadrat) between the six and single flock study.

The greatest number of hens per quadrat recorded in the apron zone appeared to be associated with reduced NND which increased further into the range as the number of hens in the range decreased. The increased distance between individual hens in the distant part of the range was also associated with increased movement and exploration (e.g. Keeling and Duncan, 1991; Keeling 1994) and based on this, the amount of space between individual hens appeared to have influenced their choice of behaviour. The reports of the two studies presented in this thesis showed that the hens observed had similar behavioural patterns as there was a slight difference between the proportions of the recorded behaviours (Table 8.1).

Also, the choice of outdoor location by the hens appeared to have influenced their feather condition as the hens found in the outer range area had better feathers compared to the apron users. This is a potential benefit derivable from using outer parts of the range but before any conclusion can be drawn, a further objective study will be required. The study will identify individual hens and feather assessing them after a period of time. This will give more insight whether regular users of outer range zone are the ones with best feathers.

Based on the reports presented in this thesis, the findings of the six-flock study agreed well with the single flock study and this suggests that the distribution and behaviour of free range laying hens can be reliably measured using either direct or photographic observation methods. This was further proven by the results of the validation of the photographic measure against video observations.

Behaviour	**Six flock study proportion (%)**	**SEM**	**Single flock study proportion (%)**	**SEM**	**Difference between studies (%)**
Resting	27.56	1.68	29.00	0.32	1.44
Locomotion	25.99	1.09	32.85	0.32	6.86
Foraging	42.73	1.64	36.32	0.32	6.41
Comfort	3.68	0.84	1.83	0.08	1.85
Aggression	0.04	0.03	0.00	0.00	0.04

Table 8.1. Table showing the proportions and differences in the proportion of resting, locomotory, foraging, comfort and aggressive behaviours between the single and six flock studies reported in this thesis. The hens in the two separate studies showed similar behavioural patterns although there were differences between the proportion of each behaviour recorded in the two studies.

The main studies presented in this thesis provided further details on the measures of behaviour and the use of range by commercial free-range laying hens compared to other studies that investigated ranging behaviour hens. While other studies provided estimates of overall outdoor use, the studies presented in this thesis explored the distribution, behaviour, NND and feather condition of the hens in the range with greater emphasis on the effect of position of the hens on their density, NND, behaviour and degree of feather damages. Also, the six-flock study presented in this thesis provided a good measure of the potential benefit of the use of different areas of the range by the hens e.g. the evidence that the hens found in the outer range zone had better feathers compared to their counterparts in the apron area. The photographic measure of behaviour of the hens was used in the single flock study presented in chapter 7 of this thesis has not been reported in the literature and based on this, it is considered a novel technique for assessing the distribution and behaviour of commercial free-range laying hens. The photographic measure of ranging behaviour provided a valuable estimate of the changes in the use of range by the hens and represents a relatively cheap and reliable alternative to the use of direct observations and the installation of CCTV cameras in the range.

Limitations of this thesis

A number of constrains was identified in the two major studies presented in this thesis. One of the major constraints identified in the two main studies was the sample sizes (6 flock in the first main study and 1 flock in the second main study) which is relatively small compared to other published studies (e.g. 50 flocks on 36 farms reported by Nicol *et al*. 2003; 63 flocks on 26 farms reported by Bestman and Wagenaar, 2003). The studies would have benefited from larger sample sizes (number of flocks) e.g. 20 - 50 commercial laying flocks. Another limitation identified in the studies was that the observations were carried out over a relatively short period of time in cross-sectional (six flock) and prospective (single flock) studies where flocks were visited within short period of time (especially the six-flock study) to obtain details of behaviour, use of range, NND and feather condition of the hens in the range. The studies would have benefited from additional visits e.g. observing each for an entire production cycle, to cut across all the seasons of the year. A further lengthy study would be beneficial in this case to determine if the use of range is constant throughout the production cycle following the initial period of reluctance to use the range. Also, the short daily length of observations (e.g. 9am to 2pm) was another limitation identified in the studies. Extension of the duration of observations e.g. from 8am to 6pm during each visit would have yielded greater amount of details and provide a more detailed use of range by the hens on daily basis. Other limitations identified were imbalanced flock sizes (e.g. 1 flock of 4000 hens, 3 flocks of 16000 hens, 1 flock of 8000 hens and 1 flock of 24000 hens) and fewer number of strains (i.e. Hyline and Lohmann Brown strains). While flock size was found to have an effect on the use of range, it was not possible to carry out further tests to determine the flocks that differed significantly from the others in their use of range, due to this imbalanced nature of the flock sizes. A further priority study with balanced number of flock sizes (e.g. 4 flocks of 4000 hens, 4 flocks of 8000 hens, 4 flocks of 16000hens) and flock ages (e.g. 4 flocks of 30-week-old hens, 4 flocks of 35-week-old hens, 4 flocks of 40-week-old hens) would be ideally resolve this and also enable a conclusion to be made on this. Strain effect was also detected on the use of range but the generality of the effect of strain on the use of range may be more robust if more strains of laying hens were included in the studies

The single flock study was designed to minimize the observer's influence on the behaviour of the hens as identified in the prior six flock study, but there are chances that the behaviour of the hens in the photographic study was influenced by the presence of the photographer, even at the recommended 15m hen-observer distance. Although the hens were habituated to the presence of observer prior to the photographic observations to reduce the potential observer influence on their behaviour, it was still possible that some degree of behavioural disruptions had occurred during the study. It seems that a no-contact approach (e.g. use of CCTV cameras in place of the photographic or direct observations) may be the best alternative, as the potential disruptions to the behaviour of the hens by the observers would be completely removed. As good as this approach may sound, there are other limitations that researchers may encounter (e.g. high installation costs) before its benefits can be derived.

While the six-flock study provided a good estimate of range use and the potential benefits of ranging to the hens, it was not clear whether the hens that used the outdoor range were frequently found in the same or different areas of the range. A further study would be beneficial to explore likelihood of the hens to benefit from improved feather conditions through constant use of the outer range. This will provide more precise details on the use of range, in the form of the greater accuracy of the number of hens in the range, their most preferred locations, the individuals that use the different range zones, specific amount of time spent in the range and potentially, the position of the hens in relation to other individuals. This will involve the demarcation of different range areas using fences and antennae and identifying individual hens with RFID tags as well as matching the feather quality data of the hens with their specific location in the range.

The two main studies presented in this thesis provided a good estimate of the likelihood of the hens found in different parts of the range to engage in different activities but there were chances that the behaviours may have been over or under estimated. The behaviour sampling protocol involved recording of the behaviour of a reference hen and every second hen to it. This problem was rooted in the fact that social influences occur in laying hens so it was possible that some of the behaviours that were recorded had occurred more or less in the given outdoor area of the range.

Recommendations

The findings of the studies presented in this thesis suggested that the hens showed some degree of reluctance to use the range during initial period of outdoor access and this may have been a result of the lack of prior outdoor experience during rearing as reported in the literature. The hens were reared indoors before they were moved to the free-range farm prior to egg laying and during the initial egg laying period, they were not allowed access to the outdoor area, in order to encourage laying in indoor nest boxes. Based on this, providing outdoor access to the hens during rearing stage, or later in day after most eggs have been laid, may be a useful tool in reducing or even removing this period of delay in the outdoor use.

Also, in both studies, the hens showed evidence of poor use of range, increased use of the close surroundings of the shed and a drop in the number of hens as the distance from the shed increased. This common problem has been reported in other published studies and it seems to be associated with the poor level of cover provided in the range. The trees found in the outdoor range of the studied flocks were at the sapling stage and provided little or no cover for the hens. Trees normally take some time to develop and provide the required cover for the hens, so it may be beneficial provide additional of cover in the range (e.g. artificial shelters, chicken coops) in all parts of the range during this period of development to encourage and sustain range use while the trees develop to full canopy. It is likely that the additional covers would cushion the effects of bad weather elements (e.g. rain and wind) and at same time protect the hens from potential predators or their perception of predatory threats.

Range use was found to have an inverse relationship with flock size in the six-flock study suggesting that reducing the number of individuals in commercial laying flocks will encourage more hens to use the range. The studies presented in this thesis did not explore the actual number of hens that flocks of laying hens should have to achieve greater outdoor turn-out, but they suggested that a reduction in flock size is a potential solution to the poor use of range reported in laying hens. Further studies would be beneficial to determine the most effective number of hens that the flocks may have to encourage maximum use of range, but maintaining the cost effectiveness of larger flock numbers.

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Appendix

GLM analysis format for all the models developed for six flock study

Distribution model simplification
Model simplification

Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Number of hens					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	329547.208[a]	29	11363.697	164.610	.000
Intercept	578.588	1	578.588	8.381	.004
Zone	741.196	2	370.598	5.368	.005
Strain	163.984	1	163.984	2.375	.123
Time	14498.469	3	4832.823	70.006	.000
Popholes	9.604	1	9.604	.139	.709
FlockSize	1506.245	1	1506.245	21.819	.000
Age	1175.256	1	1175.256	17.024	.000
Temp	1184.998	1	1184.998	17.165	.000
RH	475.676	1	475.676	6.890	.009
Zone * Strain	626.380	2	313.190	4.537	.011
Zone * Time	13432.324	6	2238.721	32.429	.000
Zone * Popholes	754.168	2	377.084	5.462	.004
Zone * FlockSize	1036.698	2	518.349	7.509	.001
Zone * Age	281.058	2	140.529	2.036	.131
Zone * Temp	198.450	2	99.225	1.437	.238
Zone * RH	579.133	2	289.567	4.195	.015
Error	289529.166	4194	69.034		
Total	822359.000	4224			
Corrected Total	619076.375	4223			
a. R Squared = .532 (Adjusted R Squared = .529)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Number of hens					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.

Corrected Model	329348.758[a]	27	12198.102	176.660	.000
Intercept	775.508	1	775.508	11.231	.001
Zone	1186.277	2	593.138	8.590	.000
Strain	163.663	1	163.663	2.370	.124
Time	14372.312	3	4790.771	69.383	.000
Popholes	11.579	1	11.579	.168	.682
FlockSize	1565.493	1	1565.493	22.672	.000
Age	1056.851	1	1056.851	15.306	.000
Temp	1165.488	1	1165.488	16.879	.000
RH	452.551	1	452.551	6.554	.010
Zone * Strain	625.859	2	312.930	4.532	.011
Zone * Time	13292.483	6	2215.414	32.085	.000
Zone * Popholes	747.733	2	373.866	5.415	.004
Zone * FlockSize	1113.551	2	556.776	8.064	.000
Zone * Age	182.319	2	91.160	1.320	.267
Zone * RH	549.915	2	274.958	3.982	.019
Error	289727.617	4196	69.049		
Total	822359.000	4224			
Corrected Total	619076.375	4223			
a. R Squared = .532 (Adjusted R Squared = .529)					

Step 3

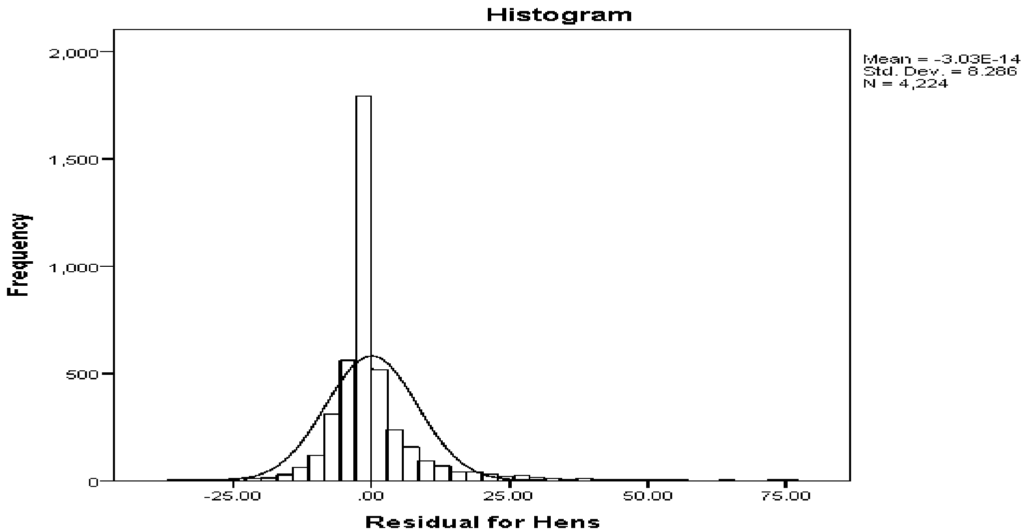
Tests of Between-Subjects Effects					
Dependent Variable: Number of hens					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	329166.439[a]	25	13166.658	190.658	.000
Intercept	1680.846	1	1680.846	24.339	.000
Zone	9015.296	2	4507.648	65.272	.000
Strain	431.089	1	431.089	6.242	.013
Time	14372.458	3	4790.819	69.373	.000
Popholes	1.348	1	1.348	.020	.889
FlockSize	2722.095	1	2722.095	39.417	.000
Age	1041.316	1	1041.316	15.079	.000
Temp	1165.488	1	1165.488	16.877	.000
RH	451.874	1	451.874	6.543	.011
Zone * Strain	1895.698	2	947.849	13.725	.000

Zone * Time	13292.703	6	2215.450	32.081	.000
Zone * Popholes	916.250	2	458.125	6.634	.001
Zone * FlockSize	4375.839	2	2187.919	31.682	.000
Zone * RH	549.087	2	274.543	3.975	.019
Error	289909.936	4198	69.059		
Total	822359.000	4224			
Corrected Total	619076.375	4223			
a. R Squared = .532 (Adjusted R Squared = .529)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Number of hens					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	329166.439[a]	25	13166.658	190.658	.000
Intercept	1680.846	1	1680.846	24.339	.000
Zone	9015.296	2	4507.648	65.272	.000
Strain	431.089	1	431.089	6.242	.013
Time	14372.458	3	4790.819	69.373	.000
FlockSize	2722.095	1	2722.095	39.417	.000
Age	1041.316	1	1041.316	15.079	.000
Temp	1165.488	1	1165.488	16.877	.000
RH	451.874	1	451.874	6.543	.011
Zone * Strain	1895.698	2	947.849	13.725	.000
Zone * Time	13292.703	6	2215.450	32.081	.000
Zone * Popholes	918.729	3	306.243	4.435	.004
Zone * FlockSize	4375.839	2	2187.919	31.682	.000
Zone * RH	549.087	2	274.543	3.975	.019
Error	289909.936	4198	69.059		
Total	822359.000	4224			
Corrected Total	619076.375	4223			
a. R Squared = .532 (Adjusted R Squared = .529)					

Normal distribution curve for the residual of the fitted distribution model



Main effects

Zone

Pairwise Comparisons						
Dependent Variable: Number of hens						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron zone	Enriched zone	21.451*	.537	.000	20.164	22.737
	Outer range zone	29.345*	.519	.000	28.102	30.588
Enriched zone	Apron zone	-21.451*	.537	.000	-22.737	-20.164
	Outer range zone	7.894*	.310	.000	7.152	8.637
Outer range zone	Apron zone	-29.345*	.519	.000	-30.588	-28.102
	Enriched zone	-7.894*	.310	.000	-8.637	-7.152
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Strain

Pairwise Comparisons
Dependent Variable: Number of hens

(I) Strain of hens	(J) Strain of hens	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Hyline	Lohmann Brown	-1.754*	.702	.013	-3.130	-.378
Lohmann Brown	Hyline	1.754*	.702	.013	.378	3.130
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Report			
Strain of hens		Flock size	Age
Hyline	Mean	8924.3333	43.3333
	N	3	3
	Std. Deviation	6003.63026	14.57166
	Std. Error of Mean	3466.19755	8.41295
Lohmann Brown	Mean	18271.6667	50.6667
	N	3	3
	Std. Deviation	4572.36288	1.52753
	Std. Error of Mean	2639.85494	.88192
Total	Mean	13598.0000	47.0000
	N	6	6
	Std. Deviation	6999.41595	10.09950
	Std. Error of Mean	2857.49959	4.12311

Time of the day

Pairwise Comparisons						
Dependent Variable: Number of hens						
(I) Time periods	(J) Time periods	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1000hrs	1100hrs	4.079*	.476	.000	2.822	5.335
	1300hrs	6.282*	.477	.000	5.024	7.539
	1400hrs	5.576*	.478	.000	4.314	6.837
1100hrs	1000hrs	-4.079*	.476	.000	-5.335	-2.822

	1300hrs	2.203*	.476	.000	.946	3.459
	1400hrs	1.497*	.477	.010	.238	2.756
1300hrs	1000hrs	-6.282*	.477	.000	-7.539	-5.024
	1100hrs	-2.203*	.476	.000	-3.459	-.946
	1400hrs	-.706	.477	.832	-1.964	.552
1400hrs	1000hrs	-5.576*	.478	.000	-6.837	-4.314
	1100hrs	-1.497*	.477	.010	-2.756	-.238
	1300hrs	.706	.477	.832	-.552	1.964
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Pop hole location

Pairwise Comparisons						
Dependent Variable: Number of hens						
(I) Pop hole location	(J) Pop hole location	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
One sided	Two sided	-.077	.552	.889	-1.159	1.005
Two sided	One sided	.077	.552	.889	-1.005	1.159
Based on estimated marginal means						
a. Adjustment for multiple comparisons: Bonferroni.						

Flock size

Descriptives								
Number of hens								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	MaXimum
					Lower Bound	Upper Bound		
3900 hens	704	9.8210	14.00454	.52782	8.7847	10.8573	.00	102.00
7300 hens	704	8.0597	12.17929	.45902	7.1584	8.9609	.00	82.00
15470 hens	704	6.5923	11.89786	.44842	5.7119	7.4727	.00	98.00
15573 hens	704	5.2841	10.59947	.39948	4.4998	6.0684	.00	62.00
15797 hens	704	6.7472	11.42973	.43077	5.9014	7.5929	.00	71.00

23548 hens	704	5.1193	11.65422	.43923	4.2569	5.9817	.00	95.00
Total	4224	6.9373	12.10770	.18629	6.5720	7.3025	.00	102.00

Apron- interaction post hoc tests and correlation coefficients

Strains

Anova					
Number of hens per quadrat/apron					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	14.648	1	14.648	.042	.837
Within groups	132200.099	382	346.074		
Total	132214.747	383			

Time of the day

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	15963.508	3	5321.169	17.394	.000
Within groups	116251.240	380	305.924		
Total	132214.747	383			

Multiple comparisons						
Dependent variable: number of hens per quadrat/apron						
Bonferroni						
(i) time of the day	(j) time of the day	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
10am	11am	11.51042*	2.52456	.000	4.8149	18.2059
	1pm	17.13542*	2.52456	.000	10.4399	23.8309
	2pm	13.82292*	2.52456	.000	7.1274	20.5184
11am	10am	-11.51042*	2.52456	.000	-18.2059	-4.8149
	1pm	5.62500	2.52456	.159	-1.0705	12.3205
	2pm	2.31250	2.52456	1.000	-4.3830	9.0080
1pm	10am	-17.13542*	2.52456	.000	-23.8309	-10.4399

	11am	-5.62500	2.52456	.159	-12.3205	1.0705
	2pm	-3.31250	2.52456	1.000	-10.0080	3.3830
2pm	10am	-13.82292*	2.52456	.000	-20.5184	-7.1274
	11am	-2.31250	2.52456	1.000	-9.0080	4.3830
	1pm	3.31250	2.52456	1.000	-3.3830	10.0080
*. The mean difference is significant at the 0.05 level.						

Position of pop holes

Anova					
Number of hens per quadrat/apron					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	280.333	1	280.333	.812	.368
Within groups	131934.414	382	345.378		
Total	132214.747	383			

Temp and RH coefficients

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1832.589	2	916.295	2.678	.070[b]
	Residual	130382.158	381	342.210		
	Total	132214.747	383			
a. Dependent Variable: Number of hens per quadrat						
b. Predictors: (Constant), Relative Humidity, Temperature						

Enriched- interaction post hoc tests and correlation coefficients

Strain

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	4180.440	1	4180.440	42.045	.000
Within groups	152521.799	1534	99.428		
Total	156702.240	1535			

Time of the day

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	779.630	3	259.877	2.553	.054
Within groups	155922.609	1532	101.777		
Total	156702.240	1535			

Multiple comparisons						
Dependent variable: number of hens per quadrat						
Bonferroni						
(i) time of the day	(j) time of the day	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
10am	11am	.65885	.72807	1.000	-1.2645	2.5822
	1pm	1.69271	.72807	.121	-.2306	3.6160
	2pm	1.65885	.72807	.137	-.2645	3.5822
11am	10am	-.65885	.72807	1.000	-2.5822	1.2645
	1pm	1.03385	.72807	.935	-.8895	2.9572
	2pm	1.00000	.72807	1.000	-.9233	2.9233
1pm	10am	-1.69271	.72807	.121	-3.6160	.2306
	11am	-1.03385	.72807	.935	-2.9572	.8895
	2pm	-.03385	.72807	1.000	-1.9572	1.8895
2pm	10am	-1.65885	.72807	.137	-3.5822	.2645
	11am	-1.00000	.72807	1.000	-2.9233	.9233
	1pm	.03385	.72807	1.000	-1.8895	1.9572

Position of pop hole

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	1901.657	1	1901.657	18.845	.000
Within groups	154800.583	1534	100.913		
Total	156702.240	1535			

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	3.893	1.413		2.755	.006	1.122	6.665
	Temperature	.130	.064	.052	2.028	.043	.004	.256
	Relative Humidity	.054	.017	.080	3.162	.002	.021	.088
a. Dependent Variable: Number of hens per quadrat								

Outer range- interaction post hoc tests and correlation coefficients

Strain

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	215.111	1	215.111	13.070	.000
Within groups	37887.882	2302	16.459		
Total	38102.993	2303			

Time of the day

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	304.045	3	101.348	6.167	.000
Within groups	37798.948	2300	16.434		
Total	38102.993	2303			

Multiple comparisons
Dependent variable: number of hens per quadrat
Bonferroni

(i) time of the day	(j) time of the day	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
10am	11am	-.00521	.23888	1.000	-.6360	.6256
	1pm	-.04514	.23888	1.000	-.6759	.5856
	2pm	.82118*	.23888	.004	.1904	1.4520
11am	10am	.00521	.23888	1.000	-.6256	.6360
	1pm	-.03993	.23888	1.000	-.6707	.5908
	2pm	.82639*	.23888	.003	.1956	1.4572
1pm	10am	.04514	.23888	1.000	-.5856	.6759
	11am	.03993	.23888	1.000	-.5908	.6707
	2pm	.86632*	.23888	.002	.2355	1.4971
2pm	10am	-.82118*	.23888	.004	-1.4520	-.1904
	11am	-.82639*	.23888	.003	-1.4572	-.1956
	1pm	-.86632*	.23888	.002	-1.4971	-.2355
*. The mean difference is significant at the 0.05 level.						

Position of pop hole

Anova					
Number of hens per quadrat					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	617.615	1	617.615	37.928	.000
Within groups	37485.378	2302	16.284		
Total	38102.993	2303			

Correlation coefficients

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.065	.465		.139	.889	-.847	.976
	Temperature	.073	.021	.072	3.479	.001	.032	.115
	Relative Humidity	.012	.006	.045	2.186	.029	.001	.023
a. Dependent Variable: Number of hens per quadrat								

Time of the day between zones-post hoc tests

10am

Anova					
Number of hens					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	131236.967	2	65618.484	834.760	.000
Within groups	82773.774	1053	78.608		
Total	214010.741	1055			

Multiple comparisons						
Dependent variable: number of hens						
Bonferroni						
(i) outdoor zones	(j) outdoor zones	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Apron zone	Enriched zone	31.52083*	1.01170	.000	29.0950	33.9467
	Outer range zone	39.70139*	.97739	.000	37.3578	42.0450
Enriched zone	Apron zone	-31.52083*	1.01170	.000	-33.9467	-29.0950
	Outer range zone	8.18056*	.58411	.000	6.7800	9.5811
Outer range zone	Apron zone	-39.70139*	.97739	.000	-42.0450	-37.3578
	Enriched zone	-8.18056*	.58411	.000	-9.5811	-6.7800
*. The mean difference is significant at the 0.05 level.						

11am

Anova					
Number of hens					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	68347.137	2	34173.568	460.667	.000
Within groups	78114.496	1053	74.183		
Total	146461.633	1055			

Multiple comparisons						
Dependent variable: number of hens						
Bonferroni						
(i) outdoor zones	(j) outdoor zones	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Apron zone	Enriched zone	20.66927*	.98281	.000	18.3127	23.0259
	Outer range zone	28.18576*	.94949	.000	25.9091	30.4625
Enriched zone	Apron zone	-20.66927*	.98281	.000	-23.0259	-18.3127
	Outer range zone	7.51649*	.56743	.000	6.1559	8.8771
Outer range zone	Apron zone	-28.18576*	.94949	.000	-30.4625	-25.9091
	Enriched zone	-7.51649*	.56743	.000	-8.8771	-6.1559
*. The mean difference is significant at the 0.05 level.						

1pm

Anova					
Number of hens					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	44276.560	2	22138.280	340.770	.000
Within groups	68408.698	1053	64.966		
Total	112685.258	1055			

Multiple comparisons						
Dependent variable: number of hens						
Bonferroni						
(i) outdoor zones	(j) outdoor zones	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Apron zone	Enriched zone	16.07813*	.91973	.000	13.8728	18.2835
	Outer range zone	22.52083*	.88854	.000	20.3903	24.6514

Enriched zone	Apron zone	-16.07813*	.91973	.000	-18.2835	-13.8728
	Outer range zone	6.44271*	.53101	.000	5.1695	7.7160
Outer range zone	Apron zone	-22.52083*	.88854	.000	-24.6514	-20.3903
	Enriched zone	-6.44271*	.53101	.000	-7.7160	-5.1695
*. The mean difference is significant at the 0.05 level.						

2pm

Anova					
Number of hens					
	Sum of squares	Df	Mean square	F	Sig.
Between groups	61701.792	2	30850.896	402.673	.000
Within groups	80675.829	1053	76.615		
Total	142377.621	1055			

Multiple comparisons						
Dependent variable: number of hens						
Bonferroni						
(i) outdoor zones	(j) outdoor zones	Mean difference (i-j)	Std. Error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Apron zone	Enriched zone	19.35677*	.99880	.000	16.9618	21.7517
	Outer range zone	26.69965*	.96493	.000	24.3859	29.0134
Enriched zone	Apron zone	-19.35677*	.99880	.000	-21.7517	-16.9618
	Outer range zone	7.34288*	.57666	.000	5.9602	8.7256
Outer range zone	Apron zone	-26.69965*	.96493	.000	-29.0134	-24.3859
	Enriched zone	-7.34288*	.57666	.000	-8.7256	-5.9602
*. The mean difference is significant at the 0.05 level.						

ANOVA						
Number of hens						
Outdoor zones		Sum of Squares	df	Mean Square	F	Sig.
Apron zone	Between Groups	6067.669	5	1213.534	3.636	.003
	Within Groups	126147.078	378	333.722		

	Total	132214.747	383			
Enriched zone	Between Groups	12492.427	5	2498.485	26.508	.000
	Within Groups	144209.813	1530	94.255		
	Total	156702.240	1535			
Outer range zone	Between Groups	1389.045	5	277.809	17.389	.000
	Within Groups	36713.948	2298	15.976		
	Total	38102.993	2303			

Strain of the hens between zones-post hoc tests

Hyline strain

ANOVA					
Number of hens					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	150109.771	2	75054.885	887.307	.000
Within Groups	178394.525	2109	84.587		
Total	328504.295	2111			

Multiple Comparisons						
Dependent Variable: Number of hens						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron zone	Enriched zone	20.45182*	.74209	.000	18.6739	22.2298
	Outer range zone	29.16667*	.71693	.000	27.4490	30.8843
Enriched zone	Apron zone	-20.45182*	.74209	.000	-22.2298	-18.6739
	Outer range zone	8.71484*	.42845	.000	7.6883	9.7414
Outer range zone	Apron zone	-29.16667*	.71693	.000	-30.8843	-27.4490
	Enriched zone	-8.71484*	.42845	.000	-9.7414	-7.6883
*. The mean difference is significant at the 0.05 level.						

Lohmann Brown strain

ANOVA					
Number of hens					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	143758.346	2	71879.173	1051.159	.000

Within Groups	144215.256	2109	68.381		
Total	287973.602	2111			

Multiple Comparisons						
Dependent Variable: Number of hens						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron zone	Enriched zone	23.36068*	.66722	.000	21.7621	24.9593
	Outer range zone	29.38715*	.64460	.000	27.8428	30.9315
Enriched zone	Apron zone	-23.36068*	.66722	.000	-24.9593	-21.7621
	Outer range zone	6.02648*	.38522	.000	5.1035	6.9494
Outer range zone	Apron zone	-29.38715*	.64460	.000	-30.9315	-27.8428
	Enriched zone	-6.02648*	.38522	.000	-6.9494	-5.1035
*. The mean difference is significant at the 0.05 level.						

Nearest neighbour distance model

Descriptives

Zones

Nearest Neighbour Distance * Outdoor zones				
Nearest Neighbour Distance				
Outdoor zones	Mean	N	Std. Deviation	Std. Error of Mean
Apron	1.6177	960	1.57373	.05079
Enriched	2.3999	960	2.55904	.08259
Range	5.5682	960	4.66579	.15059
Total	3.1953	2880	3.62991	.06764

Age

Nearest Neighbour Distance * Age
Nearest Neighbour Distance

Age	Mean	N	Std. Deviation	Std. Error of Mean
27.00	2.0715	480	2.64176	.12058
48.00	3.3356	480	3.28472	.14993
49.00	2.7685	480	2.88521	.13169
51.00	3.9700	480	3.85877	.17613
52.00	3.1315	480	3.54025	.16159
55.00	3.8946	480	4.80787	.21945
Total	3.1953	2880	3.62991	.06764

Flock size

Nearest Neighbour Distance * Flock Size				
Nearest Neighbour Distance				
Flock Size	Mean	N	Std. Deviation	Std. Error of Mean
3900.00	3.8946	480	4.80787	.21945
7300.00	3.3356	480	3.28472	.14993
15470.00	2.7685	480	2.88521	.13169
15573.00	2.0715	480	2.64176	.12058
15797.00	3.9700	480	3.85877	.17613
23548.00	3.1315	480	3.54025	.16159
Total	3.1953	2880	3.62991	.06764

Strains

Nearest Neighbour Distance * Strain				
Nearest Neighbour Distance				
Strain	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	3.1006	1440	3.76710	.09927
Lohmann brown	3.2900	1440	3.48608	.09187
Total	3.1953	2880	3.62991	.06764

Location of pop holes

Nearest Neighbour Distance * Location of pop holes				
Nearest Neighbour Distance				
Location of pop holes	Mean	N	Std. Deviation	Std. Error of Mean
1 sided	2.9500	960	3.23280	.10434
2 sided	3.3179	1920	3.80788	.08690

Total	3.1953	2880	3.62991	.06764

Model simplification process

Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Nearest Neighbour Distance					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10332.753[a]	14	738.054	76.608	.000
Intercept	5.303	1	5.303	.550	.458
Zones	147.012	2	73.506	7.630	.000
Strain	5.325	1	5.325	.553	.457
Pophole	295.655	1	295.655	30.688	.000
Age	429.872	1	429.872	44.620	.000
Flocksize	6.393	1	6.393	.664	.415
Zones * Strain	83.822	2	41.911	4.350	.013
Zones * Pophole	90.294	2	45.147	4.686	.009
Zones * Age	487.356	2	243.678	25.293	.000
Zones * Flocksize	117.655	2	58.828	6.106	.002
Error	27601.749	2865	9.634		
Total	67338.790	2880			
Corrected Total	37934.502	2879			
a. R Squared = .272 (Adjusted R Squared = .269)					

Step 2

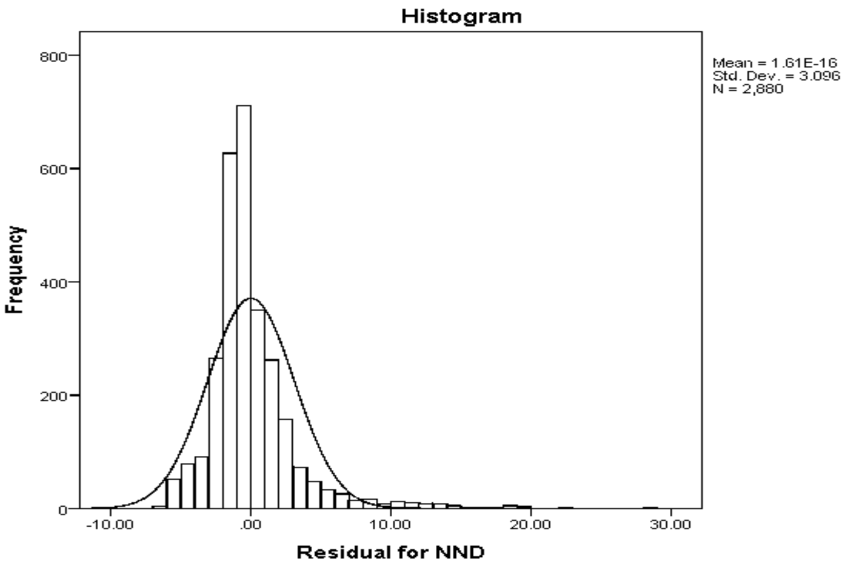
Tests of Between-Subjects Effects					
Dependent Variable: Nearest Neighbour Distance					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10332.753[a]	14	738.054	76.608	.000
Intercept	5.303	1	5.303	.550	.458
Zones	147.012	2	73.506	7.630	.000
Strain	5.325	1	5.325	.553	.457
Pophole	295.655	1	295.655	30.688	.000
Age	429.872	1	429.872	44.620	.000

Zones * Strain	83.822	2	41.911	4.350	.013
Zones * Pophole	90.294	2	45.147	4.686	.009
Zones * Age	487.356	2	243.678	25.293	.000
Zones * Flocksize	124.048	3	41.349	4.292	.005
Error	27601.749	2865	9.634		
Total	67338.790	2880			
Corrected Total	37934.502	2879			
a. R Squared = .272 (Adjusted R Squared = .269)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Nearest Neighbour Distance					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10332.753[a]	14	738.054	76.608	.000
Intercept	5.303	1	5.303	.550	.458
Zones	147.012	2	73.506	7.630	.000
Pophole	295.655	1	295.655	30.688	.000
Age	429.872	1	429.872	44.620	.000
Zones * Strain	89.147	3	29.716	3.084	.026
Zones * Pophole	90.294	2	45.147	4.686	.009
Zones * Age	487.356	2	243.678	25.293	.000
Zones * Flocksize	124.048	3	41.349	4.292	.005
Error	27601.749	2865	9.634		
Total	67338.790	2880			
Corrected Total	37934.502	2879			
a. R Squared = .272 (Adjusted R Squared = .269)					

Normal distribution curve for the residual of the fitted NND model



Main effect post hoc tests

Zone

Nearest Neighbour Distance * Outdoor zones				
Nearest Neighbour Distance				
Outdoor zones	Mean	N	Std. Deviation	Std. Error of Mean
Apron	1.6177	960	1.57373	.05079
Enriched	2.3999	960	2.55904	.08259
Range	5.5682	960	4.66579	.15059
Total	3.1953	2880	3.62991	.06764

Pairwise Comparisons						
Dependent Variable: Nearest Neighbour Distance						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron	Enriched	-.706*	.161	.000	-1.093	-.320
	Range	-3.718*	.161	.000	-4.105	-3.332
Enriched	Apron	.706*	.161	.000	.320	1.093
	Range	-3.012*	.161	.000	-3.399	-2.625
Range	Apron	3.718*	.161	.000	3.332	4.105
	Enriched	3.012*	.161	.000	2.625	3.399

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Pop hole location

Nearest Neighbour Distance * Location of pop holes				
Nearest Neighbour Distance				
Location of pop holes	Mean	N	Std. Deviation	Std. Error of Mean
1 sided	2.9500	960	3.23280	.10434
2 sided	3.3179	1920	3.80788	.08690
Total	3.1953	2880	3.62991	.06764

Pairwise Comparisons						
Dependent Variable: Nearest Neighbour Distance						
(I) Location of pop holes	(J) Location of pop holes	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1 sided	2 sided	-1.050*	.189	.000	-1.421	-.678
2 sided	1 sided	1.050*	.189	.000	.678	1.421
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Age

Nearest Neighbour Distance * Age				
Nearest Neighbour Distance				
Age	Mean	N	Std. Deviation	Std. Error of Mean
27.00	2.0715	480	2.64176	.12058
48.00	3.3356	480	3.28472	.14993
49.00	2.7685	480	2.88521	.13169
51.00	3.9700	480	3.85877	.17613
52.00	3.1315	480	3.54025	.16159
55.00	3.8946	480	4.80787	.21945
Total	3.1953	2880	3.62991	.06764

Multiple Comparisons						
Dependent Variable: Nearest Neighbour Distance						
Bonferroni						
(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
27.00	48.00	-1.26417*	.23069	.000	-1.9418	-.5865
	49.00	-.69708*	.23069	.038	-1.3748	-.0194
	51.00	-1.89854*	.23069	.000	-2.5762	-1.2209
	52.00	-1.06000*	.23069	.000	-1.7377	-.3823
	55.00	-1.82315*	.23069	.000	-2.5008	-1.1455
48.00	27.00	1.26417*	.23069	.000	.5865	1.9418
	49.00	.56708	.23069	.210	-.1106	1.2448
	51.00	-.63438	.23069	.090	-1.3121	.0433
	52.00	.20417	.23069	1.000	-.4735	.8818
	55.00	-.55898	.23069	.232	-1.2367	.1187
49.00	27.00	.69708*	.23069	.038	.0194	1.3748
	48.00	-.56708	.23069	.210	-1.2448	.1106
	51.00	-1.20146*	.23069	.000	-1.8791	-.5238
	52.00	-.36292	.23069	1.000	-1.0406	.3148
	55.00	-1.12606*	.23069	.000	-1.8037	-.4484
51.00	27.00	1.89854*	.23069	.000	1.2209	2.5762
	48.00	.63438	.23069	.090	-.0433	1.3121
	49.00	1.20146*	.23069	.000	.5238	1.8791
	52.00	.83854*	.23069	.004	.1609	1.5162
	55.00	.07540	.23069	1.000	-.6023	.7531
52.00	27.00	1.06000*	.23069	.000	.3823	1.7377
	48.00	-.20417	.23069	1.000	-.8818	.4735
	49.00	.36292	.23069	1.000	-.3148	1.0406
	51.00	-.83854*	.23069	.004	-1.5162	-.1609
	55.00	-.76315*	.23069	.014	-1.4408	-.0855
55.00	27.00	1.82315*	.23069	.000	1.1455	2.5008
	48.00	.55898	.23069	.232	-.1187	1.2367
	49.00	1.12606*	.23069	.000	.4484	1.8037
	51.00	-.07540	.23069	1.000	-.7531	.6023
	52.00	.76315*	.23069	.014	.0855	1.4408
*. The mean difference is significant at the 0.05 level.						

Flock size

Nearest Neighbour Distance * Flock Size				
Nearest Neighbour Distance				
Flock Size	Mean	N	Std. Deviation	Std. Error of Mean
3900.00	3.8946	480	4.80787	.21945
7300.00	3.3356	480	3.28472	.14993
15470.00	2.7685	480	2.88521	.13169
15573.00	2.0715	480	2.64176	.12058
15797.00	3.9700	480	3.85877	.17613
23548.00	3.1315	480	3.54025	.16159
Total	3.1953	2880	3.62991	.06764

Strain

Nearest Neighbour Distance * Strain				
Nearest Neighbour Distance				
Strain	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	3.1006	1440	3.76710	.09927
Lohmann brown	3.2900	1440	3.48608	.09187
Total	3.1953	2880	3.62991	.06764

Hyline strain X zones

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3825.401	2	1912.701	165.620	.000
Within Groups	16595.487	1437	11.549		
Total	20420.888	1439			

Multiple Comparisons						
Dependent Variable: Nearest Neighbour Distance						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound

Apron	Enriched	-.71273*	.21936	.004	-1.2385	-.1870
	Range	-3.75833*	.21936	.000	-4.2841	-3.2326
Enriched	Apron	.71273*	.21936	.004	.1870	1.2385
	Range	-3.04560*	.21936	.000	-3.5714	-2.5198
Range	Apron	3.75833*	.21936	.000	3.2326	4.2841
	Enriched	3.04560*	.21936	.000	2.5198	3.5714
*. The mean difference is significant at the 0.05 level.						

Lohmann Brown strain X zones

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4594.932	2	2297.466	256.069	.000
Within Groups	12892.844	1437	8.972		
Total	17487.776	1439			

Multiple Comparisons						
Dependent Variable: Nearest Neighbour Distance						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	-.85167*	.19335	.000	-1.3151	-.3883
	Range	-4.14271*	.19335	.000	-4.6061	-3.6793
Enriched	Apron	.85167*	.19335	.000	.3883	1.3151
	Range	-3.29104*	.19335	.000	-3.7545	-2.8276
Range	Apron	4.14271*	.19335	.000	3.6793	4.6061
	Enriched	3.29104*	.19335	.000	2.8276	3.7545
*. The mean difference is significant at the 0.05 level.						

NND post hoc tests for interactions
Apron X Age

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	149.384	5	29.877	12.806	.000
Within Groups	2225.715	954	2.333		
Total	2375.099	959			

Multiple Comparisons						
Dependent Variable: Nearest Neighbour Distance						
Bonferroni						
(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
27.00	48.00	-1.14563*	.17077	.000	-1.6481	-.6431
	49.00	-.32063	.17077	.911	-.8231	.1819
	51.00	-.74625*	.17077	.000	-1.2488	-.2437
	52.00	-.25000	.17077	1.000	-.7525	.2525
	55.00	-.12625	.17077	1.000	-.6288	.3763
48.00	27.00	1.14563*	.17077	.000	.6431	1.6481
	49.00	.82500*	.17077	.000	.3225	1.3275
	51.00	.39938	.17077	.293	-.1031	.9019
	52.00	.89563*	.17077	.000	.3931	1.3981
	55.00	1.01938*	.17077	.000	.5169	1.5219
49.00	27.00	.32063	.17077	.911	-.1819	.8231
	48.00	-.82500*	.17077	.000	-1.3275	-.3225
	51.00	-.42563	.17077	.193	-.9281	.0769
	52.00	.07063	.17077	1.000	-.4319	.5731
	55.00	.19438	.17077	1.000	-.3081	.6969
51.00	27.00	.74625*	.17077	.000	.2437	1.2488
	48.00	-.39938	.17077	.293	-.9019	.1031
	49.00	.42563	.17077	.193	-.0769	.9281
	52.00	.49625	.17077	.056	-.0063	.9988
	55.00	.62000*	.17077	.004	.1175	1.1225
52.00	27.00	.25000	.17077	1.000	-.2525	.7525
	48.00	-.89563*	.17077	.000	-1.3981	-.3931
	49.00	-.07063	.17077	1.000	-.5731	.4319

	51.00	-.49625	.17077	.056	-.9988	.0063
	55.00	.12375	.17077	1.000	-.3788	.6263
55.00	27.00	.12625	.17077	1.000	-.3763	.6288
	48.00	-1.01938*	.17077	.000	-1.5219	-.5169
	49.00	-.19438	.17077	1.000	-.6969	.3081
	51.00	-.62000*	.17077	.004	-1.1225	-.1175
	52.00	-.12375	.17077	1.000	-.6263	.3788

*. The mean difference is significant at the 0.05 level.

Apron X Flock size

ANOVA

Nearest Neighbour Distance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	149.384	5	29.877	12.806	.000
Within Groups	2225.715	954	2.333		
Total	2375.099	959			

Multiple Comparisons

Dependent Variable: Nearest Neighbour Distance

Bonferroni

(I) Flock Size	(J) Flock Size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
3900.00	7300.00	-1.01938*	.17077	.000	-1.5219	-.5169
	15470.00	-.19438	.17077	1.000	-.6969	.3081
	15573.00	.12625	.17077	1.000	-.3763	.6288
	15797.00	-.62000*	.17077	.004	-1.1225	-.1175
	23548.00	-.12375	.17077	1.000	-.6263	.3788
7300.00	3900.00	1.01938*	.17077	.000	.5169	1.5219
	15470.00	.82500*	.17077	.000	.3225	1.3275
	15573.00	1.14563*	.17077	.000	.6431	1.6481
	15797.00	.39938	.17077	.293	-.1031	.9019
	23548.00	.89563*	.17077	.000	.3931	1.3981
15470.00	3900.00	.19438	.17077	1.000	-.3081	.6969
	7300.00	-.82500*	.17077	.000	-1.3275	-.3225
	15573.00	.32063	.17077	.911	-.1819	.8231
	15797.00	-.42563	.17077	.193	-.9281	.0769
	23548.00	.07063	.17077	1.000	-.4319	.5731

15573.00	3900.00	-.12625	.17077	1.000	-.6288	.3763
	7300.00	-1.14563*	.17077	.000	-1.6481	-.6431
	15470.00	-.32063	.17077	.911	-.8231	.1819
	15797.00	-.74625*	.17077	.000	-1.2488	-.2437
	23548.00	-.25000	.17077	1.000	-.7525	.2525
15797.00	3900.00	.62000*	.17077	.004	.1175	1.1225
	7300.00	-.39938	.17077	.293	-.9019	.1031
	15470.00	.42563	.17077	.193	-.0769	.9281
	15573.00	.74625*	.17077	.000	.2437	1.2488
	23548.00	.49625	.17077	.056	-.0063	.9988
23548.00	3900.00	.12375	.17077	1.000	-.3788	.6263
	7300.00	-.89563*	.17077	.000	-1.3981	-.3931
	15470.00	-.07063	.17077	1.000	-.5731	.4319
	15573.00	.25000	.17077	1.000	-.2525	.7525
	15797.00	-.49625	.17077	.056	-.9988	.0063

*. The mean difference is significant at the 0.05 level.

Apron X Strain

ANOVA

Nearest Neighbour Distance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.054	1	.054	.022	.883
Within Groups	2375.045	958	2.479		
Total	2375.099	959			

Location of pop holes

ANOVA

Nearest Neighbour Distance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.252	1	10.252	4.153	.042
Within Groups	2364.847	958	2.469		
Total	2375.099	959			

Enriched X Age

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	333.309	5	66.662	10.694	.000
Within Groups	5946.903	954	6.234		
Total	6280.212	959			

Multiple Comparisons						
Dependent Variable: Nearest Neighbour Distance						
Bonferroni						
(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
27.00	48.00	-.54875	.27914	.744	-1.3702	.2727
	49.00	-.65313	.27914	.293	-1.4745	.1683
	51.00	-1.58188*	.27914	.000	-2.4033	-.7605
	52.00	-.25875	.27914	1.000	-1.0802	.5627
	55.00	-1.48319*	.27914	.000	-2.3046	-.6618
48.00	27.00	.54875	.27914	.744	-.2727	1.3702
	49.00	-.10438	.27914	1.000	-.9258	.7170
	51.00	-1.03313*	.27914	.003	-1.8545	-.2117
	52.00	.29000	.27914	1.000	-.5314	1.1114
	55.00	-.93444*	.27914	.013	-1.7558	-.1130
49.00	27.00	.65313	.27914	.293	-.1683	1.4745
	48.00	.10438	.27914	1.000	-.7170	.9258
	51.00	-.92875*	.27914	.014	-1.7502	-.1073
	52.00	.39438	.27914	1.000	-.4270	1.2158
	55.00	-.83006*	.27914	.045	-1.6515	-.0087
51.00	27.00	1.58188*	.27914	.000	.7605	2.4033
	48.00	1.03313*	.27914	.003	.2117	1.8545
	49.00	.92875*	.27914	.014	.1073	1.7502
	52.00	1.32313*	.27914	.000	.5017	2.1445
	55.00	.09869	.27914	1.000	-.7227	.9201
52.00	27.00	.25875	.27914	1.000	-.5627	1.0802
	48.00	-.29000	.27914	1.000	-1.1114	.5314
	49.00	-.39438	.27914	1.000	-1.2158	.4270
	51.00	-1.32313*	.27914	.000	-2.1445	-.5017
	55.00	-1.22444*	.27914	.000	-2.0458	-.4030

55.00	27.00	1.48319*	.27914	.000	.6618	2.3046
	48.00	.93444*	.27914	.013	.1130	1.7558
	49.00	.83006*	.27914	.045	.0087	1.6515
	51.00	-.09869	.27914	1.000	-.9201	.7227
	52.00	1.22444*	.27914	.000	.4030	2.0458

*. The mean difference is significant at the 0.05 level.

Enriched X Flock size

ANOVA

Nearest Neighbour Distance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	333.309	5	66.662	10.694	.000
Within Groups	5946.903	954	6.234		
Total	6280.212	959			

Multiple Comparisons

Dependent Variable: Nearest Neighbour Distance

Bonferroni

(I) Flock Size	(J) Flock Size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
3900.00	7300.00	.93444*	.27914	.013	.1130	1.7558
	15470.00	.83006*	.27914	.045	.0087	1.6515
	15573.00	1.48319*	.27914	.000	.6618	2.3046
	15797.00	-.09869	.27914	1.000	-.9201	.7227
	23548.00	1.22444*	.27914	.000	.4030	2.0458
7300.00	3900.00	-.93444*	.27914	.013	-1.7558	-.1130
	15470.00	-.10438	.27914	1.000	-.9258	.7170
	15573.00	.54875	.27914	.744	-.2727	1.3702
	15797.00	-1.03313*	.27914	.003	-1.8545	-.2117
	23548.00	.29000	.27914	1.000	-.5314	1.1114
15470.00	3900.00	-.83006*	.27914	.045	-1.6515	-.0087
	7300.00	.10438	.27914	1.000	-.7170	.9258
	15573.00	.65313	.27914	.293	-.1683	1.4745
	15797.00	-.92875*	.27914	.014	-1.7502	-.1073
	23548.00	.39438	.27914	1.000	-.4270	1.2158
15573.00	3900.00	-1.48319*	.27914	.000	-2.3046	-.6618
	7300.00	-.54875	.27914	.744	-1.3702	.2727

	15470.00	-.65313	.27914	.293	-1.4745	.1683
	15797.00	-1.58188*	.27914	.000	-2.4033	-.7605
	23548.00	-.25875	.27914	1.000	-1.0802	.5627
15797.00	3900.00	.09869	.27914	1.000	-.7227	.9201
	7300.00	1.03313*	.27914	.003	.2117	1.8545
	15470.00	.92875*	.27914	.014	.1073	1.7502
	15573.00	1.58188*	.27914	.000	.7605	2.4033
	23548.00	1.32313*	.27914	.000	.5017	2.1445
23548.00	3900.00	-1.22444*	.27914	.000	-2.0458	-.4030
	7300.00	-.29000	.27914	1.000	-1.1114	.5314
	15470.00	-.39438	.27914	1.000	-1.2158	.4270
	15573.00	.25875	.27914	1.000	-.5627	1.0802
	15797.00	-1.32313*	.27914	.000	-2.1445	-.5017
*. The mean difference is significant at the 0.05 level.						

Enriched X Strain

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.687	1	5.687	.868	.352
Within Groups	6274.525	958	6.550		
Total	6280.212	959			

Enriched X Location of pop holes

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	42.724	1	42.724	6.562	.011
Within Groups	6237.488	958	6.511		
Total	6280.212	959			

Outer range X Age

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.

Between Groups	1657.871	5	331.574	16.459	.000
Within Groups	19219.170	954	20.146		
Total	20877.041	959			

Multiple Comparisons

Dependent Variable: Nearest Neighbour Distance

Bonferroni

(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
27.00	48.00	-2.09813*	.50182	.000	-3.5748	-.6215
	49.00	-1.11750	.50182	.393	-2.5942	.3592
	51.00	-3.36750*	.50182	.000	-4.8442	-1.8908
	52.00	-2.67125*	.50182	.000	-4.1479	-1.1946
	55.00	-3.86000*	.50182	.000	-5.3367	-2.3833
48.00	27.00	2.09813*	.50182	.000	.6215	3.5748
	49.00	.98063	.50182	.765	-.4960	2.4573
	51.00	-1.26938	.50182	.174	-2.7460	.2073
	52.00	-.57313	.50182	1.000	-2.0498	.9035
	55.00	-1.76188*	.50182	.007	-3.2385	-.2852
49.00	27.00	1.11750	.50182	.393	-.3592	2.5942
	48.00	-.98063	.50182	.765	-2.4573	.4960
	51.00	-2.25000*	.50182	.000	-3.7267	-.7733
	52.00	-1.55375*	.50182	.030	-3.0304	-.0771
	55.00	-2.74250*	.50182	.000	-4.2192	-1.2658
51.00	27.00	3.36750*	.50182	.000	1.8908	4.8442
	48.00	1.26938	.50182	.174	-.2073	2.7460
	49.00	2.25000*	.50182	.000	.7733	3.7267
	52.00	.69625	.50182	1.000	-.7804	2.1729
	55.00	-.49250	.50182	1.000	-1.9692	.9842
52.00	27.00	2.67125*	.50182	.000	1.1946	4.1479
	48.00	.57313	.50182	1.000	-.9035	2.0498
	49.00	1.55375*	.50182	.030	.0771	3.0304
	51.00	-.69625	.50182	1.000	-2.1729	.7804
	55.00	-1.18875	.50182	.271	-2.6654	.2879
55.00	27.00	3.86000*	.50182	.000	2.3833	5.3367
	48.00	1.76188*	.50182	.007	.2852	3.2385
	49.00	2.74250*	.50182	.000	1.2658	4.2192
	51.00	.49250	.50182	1.000	-.9842	1.9692

	52.00	1.18875	.50182	.271	-.2879	2.6654
*. The mean difference is significant at the 0.05 level.						

Outer range X Flock size

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1657.871	5	331.574	16.459	.000
Within Groups	19219.170	954	20.146		
Total	20877.041	959			

Multiple Comparisons						
Dependent Variable: Nearest Neighbour Distance						
Bonferroni						
(I) Flock Size	(J) Flock Size	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
3900.00	7300.00	1.76188*	.50182	.007	.2852	3.2385
	15470.00	2.74250*	.50182	.000	1.2658	4.2192
	15573.00	3.86000*	.50182	.000	2.3833	5.3367
	15797.00	.49250	.50182	1.000	-.9842	1.9692
	23548.00	1.18875	.50182	.271	-.2879	2.6654
7300.00	3900.00	-1.76188*	.50182	.007	-3.2385	-.2852
	15470.00	.98063	.50182	.765	-.4960	2.4573
	15573.00	2.09813*	.50182	.000	.6215	3.5748
	15797.00	-1.26938	.50182	.174	-2.7460	.2073
	23548.00	-.57313	.50182	1.000	-2.0498	.9035
15470.00	3900.00	-2.74250*	.50182	.000	-4.2192	-1.2658
	7300.00	-.98063	.50182	.765	-2.4573	.4960
	15573.00	1.11750	.50182	.393	-.3592	2.5942
	15797.00	-2.25000*	.50182	.000	-3.7267	-.7733
	23548.00	-1.55375*	.50182	.030	-3.0304	-.0771
15573.00	3900.00	-3.86000*	.50182	.000	-5.3367	-2.3833
	7300.00	-2.09813*	.50182	.000	-3.5748	-.6215
	15470.00	-1.11750	.50182	.393	-2.5942	.3592
	15797.00	-3.36750*	.50182	.000	-4.8442	-1.8908
	23548.00	-2.67125*	.50182	.000	-4.1479	-1.1946
15797.00	3900.00	-.49250	.50182	1.000	-1.9692	.9842

	7300.00	1.26938	.50182	.174	-.2073	2.7460
	15470.00	2.25000*	.50182	.000	.7733	3.7267
	15573.00	3.36750*	.50182	.000	1.8908	4.8442
	23548.00	.69625	.50182	1.000	-.7804	2.1729
23548.00	3900.00	-1.18875	.50182	.271	-2.6654	.2879
	7300.00	.57313	.50182	1.000	-.9035	2.0498
	15470.00	1.55375*	.50182	.030	.0771	3.0304
	15573.00	2.67125*	.50182	.000	1.1946	4.1479
	15797.00	-.69625	.50182	1.000	-2.1729	.7804
*. The mean difference is significant at the 0.05 level.						

Outer range X Strain

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38.280	1	38.280	1.760	.185
Within Groups	20838.761	958	21.752		
Total	20877.041	959			

Location of pop holes

ANOVA					
Nearest Neighbour Distance					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	40.746	1	40.746	1.873	.171
Within Groups	20836.295	958	21.750		
Total	20877.041	959			

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
NND * Outdoor zones	Between Groups	(Combined)	2662.391	2	1331.195	173.089	.000
	Within Groups		7360.109	957	7.691		
	Total		10022.500	959			

Location of pop hole X zone
Single sided x zone

Report			
NND			
Outdoor zones	Mean	N	Std. Error of Mean
Apron	1.4716	320	.07434
Enriched	2.1016	320	.11283
Outer range	5.2769	320	.23204
Total	2.9500	960	.10434

Double sided x Zone

Report			
NND			
Outdoor zones	Mean	N	Std. Error of Mean
Apron	1.6908	640	.06636
Enriched	2.5491	640	.10988
Outer range	5.7139	640	.19367
Total	3.3179	1920	.08690

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
NND * Outdoor zones	Between Groups	(Combined)	5746.847	2	2873.424	249.489	.000
	Within Groups		22078.520	1917	11.517		
	Total		27825.367	1919			

Age X zones
27 WEEKS

ANOVA

NND					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	429.401	2	214.701	35.151	.000
Within Groups	2913.478	477	6.108		
Total	3342.879	479			

Multiple Comparisons						
Dependent Variable: NND						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	-.45938	.27631	.291	-1.1232	.2045
	Outer range	-2.19625*	.27631	.000	-2.8601	-1.5324
Enriched	Apron	.45938	.27631	.291	-.2045	1.1232
	Outer range	-1.73688*	.27631	.000	-2.4007	-1.0730
Outer range	Apron	2.19625*	.27631	.000	1.5324	2.8601
	Enriched	1.73688*	.27631	.000	1.0730	2.4007
*. The mean difference is significant at the 0.05 level.						

48 WEEKS

ANOVA					
NND					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1105.758	2	552.879	64.919	.000
Within Groups	4062.362	477	8.516		
Total	5168.121	479			

Multiple Comparisons						
Dependent Variable: NND						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	.13750	.32628	1.000	-.6464	.9214

	Outer range	-3.14875*	.32628	.000	-3.9326	-2.3649
Enriched	Apron	-.13750	.32628	1.000	-.9214	.6464
	Outer range	-3.28625*	.32628	.000	-4.0701	-2.5024
Outer range	Apron	3.14875*	.32628	.000	2.3649	3.9326
	Enriched	3.28625*	.32628	.000	2.5024	4.0701
*. The mean difference is significant at the 0.05 level.						

49 WEEKS

ANOVA					
NND					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	769.673	2	384.836	57.049	.000
Within Groups	3217.722	477	6.746		
Total	3987.395	479			

Multiple Comparisons						
Dependent Variable: NND						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	-.79188*	.29038	.020	-1.4895	-.0942
	Outer range	-2.99313*	.29038	.000	-3.6908	-2.2955
Enriched	Apron	.79188*	.29038	.020	.0942	1.4895
	Outer range	-2.20125*	.29038	.000	-2.8989	-1.5036
Outer range	Apron	2.99313*	.29038	.000	2.2955	3.6908
	Enriched	2.20125*	.29038	.000	1.5036	2.8989
*. The mean difference is significant at the 0.05 level.						

51 WEEKS

ANOVA					
NND					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1988.978	2	994.489	92.230	.000

Within Groups	5143.370	477	10.783		
Total	7132.348	479			

Multiple Comparisons						
Dependent Variable: NND						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	-1.29500*	.36713	.001	-2.1770	-.4130
	Outer range	-4.81750*	.36713	.000	-5.6995	-3.9355
Enriched	Apron	1.29500*	.36713	.001	.4130	2.1770
	Outer range	-3.52250*	.36713	.000	-4.4045	-2.6405
Outer range	Apron	4.81750*	.36713	.000	3.9355	5.6995
	Enriched	3.52250*	.36713	.000	2.6405	4.4045
*. The mean difference is significant at the 0.05 level.						

52 WEEKS

ANOVA					
NND					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2067.081	2	1033.540	125.241	.000
Within Groups	3936.414	477	8.252		
Total	6003.495	479			

Multiple Comparisons						
Dependent Variable: NND						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	-.46813	.32118	.437	-1.2397	.3035
	Outer range	-4.61750*	.32118	.000	-5.3891	-3.8459
Enriched	Apron	.46813	.32118	.437	-.3035	1.2397

	Outer range	-4.14938*	.32118	.000	-4.9210	-3.3778
Outer range	Apron	4.61750*	.32118	.000	3.8459	5.3891
	Enriched	4.14938*	.32118	.000	3.3778	4.9210
*. The mean difference is significant at the 0.05 level.						

55 WEEKS

ANOVA					
NND					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2953.937	2	1476.968	86.779	.000
Within Groups	8118.441	477	17.020		
Total	11072.378	479			

Multiple Comparisons						
Dependent Variable: NND						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	-1.81631*	.46125	.000	-2.9244	-.7082
	Outer range	-5.93000*	.46125	.000	-7.0381	-4.8219
Enriched	Apron	1.81631*	.46125	.000	.7082	2.9244
	Outer range	-4.11369*	.46125	.000	-5.2218	-3.0056
Outer range	Apron	5.93000*	.46125	.000	4.8219	7.0381
	Enriched	4.11369*	.46125	.000	3.0056	5.2218
*. The mean difference is significant at the 0.05 level.						

Feather score model simplification
Step 1

Tests of Between-Subjects Effects					
Dependent Variable: FEATHER SCORE					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.

Corrected Model	1105.452[a]	27	40.943	276.551	.000
Intercept	8.637	1	8.637	58.342	.000
BODYPART	4.207	3	1.402	9.472	.000
Strain	3.202	1	3.202	21.627	.000
Zone	218.689	2	109.345	738.580	.000
Pophole	.257	1	.257	1.739	.187
Age	3.071	1	3.071	20.741	.000
Flocksize	.003	1	.003	.017	.895
BODYPART * Strain	4.677	3	1.559	10.530	.000
BODYPART * Zone	229.695	6	38.283	258.583	.000
BODYPART * Pophole	.118	3	.039	.266	.850
BODYPART * Age	2.466	3	.822	5.551	.001
BODYPART * Flocksize	3.763	3	1.254	8.473	.000
Error	1701.359	11492	.148		
Total	3367.640	11520			
Corrected Total	2806.811	11519			
a. R Squared = .394 (Adjusted R Squared = .392)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: FEATHER SCORE					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1105.334[a]	24	46.056	311.147	.000
Intercept	8.637	1	8.637	58.353	.000
BODYPART	5.571	3	1.857	12.545	.000
Strain	3.202	1	3.202	21.632	.000
Zone	218.689	2	109.345	738.721	.000
Pophole	.257	1	.257	1.739	.187
Age	3.071	1	3.071	20.745	.000
Flocksize	.003	1	.003	.017	.895
BODYPART * Strain	4.610	3	1.537	10.381	.000
BODYPART * Zone	229.695	6	38.283	258.633	.000
BODYPART * Age	3.047	3	1.016	6.861	.000
BODYPART * Flocksize	4.756	3	1.585	10.711	.000
Error	1701.477	11495	.148		
Total	3367.640	11520			
Corrected Total	2806.811	11519			
a. R Squared = .394 (Adjusted R Squared = .393)					

Step 3

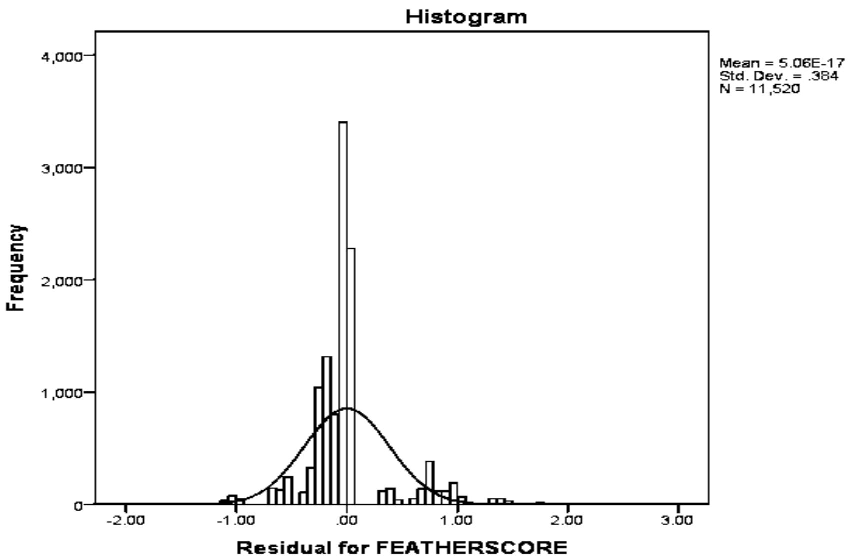
Tests of Between-Subjects Effects					
Dependent Variable: FEATHER SCORE					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1105.334[a]	24	46.056	311.147	.000
Intercept	8.637	1	8.637	58.353	.000
BODYPART	5.571	3	1.857	12.545	.000
Strain	3.202	1	3.202	21.632	.000
Zone	218.689	2	109.345	738.721	.000
Pophole	.257	1	.257	1.739	.187
Age	3.071	1	3.071	20.745	.000
BODYPART * Strain	4.610	3	1.537	10.381	.000
BODYPART * Zone	229.695	6	38.283	258.633	.000
BODYPART * Age	3.047	3	1.016	6.861	.000
BODYPART * Flocksize	4.759	4	1.190	8.037	.000
Error	1701.477	11495	.148		
Total	3367.640	11520			
Corrected Total	2806.811	11519			
a. R Squared = .394 (Adjusted R Squared = .393)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: FEATHER SCORE					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1105.077[a]	23	48.047	324.578	.000
Intercept	11.602	1	11.602	78.377	.000
BODYPART	5.571	3	1.857	12.545	.000
Strain	3.076	1	3.076	20.782	.000
Zone	218.689	2	109.345	738.674	.000
Age	3.969	1	3.969	26.814	.000
BODYPART * Strain	4.610	3	1.537	10.381	.000
BODYPART * Zone	229.695	6	38.283	258.616	.000
BODYPART * Age	3.047	3	1.016	6.861	.000
BODYPART * Flocksize	4.833	4	1.208	8.163	.000
Error	1701.735	11496	.148		
Total	3367.640	11520			

Corrected Total	2806.811	11519			
a. R Squared = .394 (Adjusted R Squared = .392)					

Normal curve for feather score residual



Descriptive

Body parts

FEATHER SCORE * BODY PART				
FEATHER SCORE				
BODY PART	Mean	N	Std. Deviation	Std. Error of Mean
NECK	.6094	2880	.71153	.01326
CHEST	.1924	2880	.41062	.00765
SIDE	.0028	2880	.05264	.00098
BACK	.0781	2880	.27837	.00519
Total	.2206	11520	.49363	.00460

Age

FEATHER SCORE * Age of Flock				
FEATHER SCORE				
Age of Flock	Mean	N	Std. Deviation	Std. Error of Mean
27.00	.2391	1920	.50597	.01155
48.00	.2135	1920	.51067	.01165
49.00	.2447	1920	.50875	.01161

51.00	.2526	1920	.50038	.01142
52.00	.2313	1920	.50908	.01162
55.00	.1427	1920	.41147	.00939
Total	.2206	11520	.49363	.00460

Flock size

FEATHER SCORE * Flock Size				
FEATHER SCORE				
Flock Size	Mean	N	Std. Deviation	Std. Error of Mean
3900.00	.1427	1920	.41147	.00939
7300.00	.2135	1920	.51067	.01165
15470.00	.2447	1920	.50875	.01161
15573.00	.2391	1920	.50597	.01155
15797.00	.2526	1920	.50038	.01142
23548.00	.2313	1920	.50908	.01162
Total	.2206	11520	.49363	.00460

Strain

FEATHER SCORE * Strain of Flock				
FEATHER SCORE				
Strain of Flock	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	.1984	5760	.47988	.00632
Lohmann Brown	.2428	5760	.50607	.00667
Total	.2206	11520	.49363	.00460

Pop hole location

FEATHER SCORE * Pop hole location				
FEATHER SCORE				
Pop hole location	Mean	N	Std. Deviation	Std. Error of Mean
1 sided	.2380	3840	.50889	.00821
2 sided	.2120	7680	.48562	.00554
Total	.2206	11520	.49363	.00460

Zones

FEATHER SCORE * Outdoor zones

FEATHER SCORE				
Outdoor zones	Mean	N	Std. Deviation	Std. Error of Mean
Apron	.3947	3840	.60503	.00976
Enriched	.2094	3840	.49789	.00803
Outer range	.0578	3840	.24539	.00396
Total	.2206	11520	.49363	.00460

Main effects

Body parts

Pairwise Comparisons						
Dependent Variable: FEATHER SCORE						
(I) BODY PART	(J) BODY PART	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
NECK	CHEST	.417*	.010	.000	.390	.444
	SIDE	.607*	.010	.000	.580	.633
	BACK	.531*	.010	.000	.505	.558
CHEST	NECK	-.417*	.010	.000	-.444	-.390
	SIDE	.190*	.010	.000	.163	.216
	BACK	.114*	.010	.000	.088	.141
SIDE	NECK	-.607*	.010	.000	-.633	-.580
	CHEST	-.190*	.010	.000	-.216	-.163
	BACK	-.075*	.010	.000	-.102	-.049
BACK	NECK	-.531*	.010	.000	-.558	-.505
	CHEST	-.114*	.010	.000	-.141	-.088
	SIDE	.075*	.010	.000	.049	.102
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Strain

Pairwise Comparisons						
Dependent Variable: FEATHER SCORE						
(I) Strain of Flock	(J) Strain of Flock	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Hyline	Lohmann Brown	-.077*	.017	.000	-.110	-.044

Lohmann Brown	Hyline	.077*	.017	.000	.044	.110
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Zones

Pairwise Comparisons

Dependent Variable: FEATHER SCORE

(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron	Enriched	.185*	.009	.000	.164	.206
	Range	.337*	.009	.000	.316	.358
Enriched	Apron	-.185*	.009	.000	-.206	-.164
	Range	.152*	.009	.000	.131	.173
Outer range	Apron	-.337*	.009	.000	-.358	-.316
	Enriched	-.152*	.009	.000	-.173	-.131

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Interactions

Neck feathers

Zone

Descriptives

FEATHER SCORE

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Apron	960	1.0635	.63371	.02045	1.0234	1.1037	.00	3.00
Enriched	960	.6104	.74362	.02400	.5633	.6575	.00	3.00

Outer range	960	.1542	.38909	.01256	.1295	.1788	.00	2.00
Total	2880	.6094	.71153	.01326	.5834	.6354	.00	3.00

ANOVA					
FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	396.944	2	198.472	538.376	.000
Within Groups	1060.603	2877	.369		
Total	1457.547	2879			

Multiple Comparisons						
Dependent Variable: FEATHER SCORE						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	.45313*	.02771	.000	.3867	.5195
	Outer range	.90938*	.02771	.000	.8430	.9758
Enriched	Apron	-.45313*	.02771	.000	-.5195	-.3867
	Outer range	.45625*	.02771	.000	.3899	.5226
Outer range	Apron	-.90938*	.02771	.000	-.9758	-.8430
	Enriched	-.45625*	.02771	.000	-.5226	-.3899
*. The mean difference is significant at the 0.05 level.						

Strain

Descriptives								
FEATHER SCORE								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Hyline	1440	.5785	.71572	.01886	.5415	.6155	.00	3.00
Lohmann Brown	1440	.6403	.70620	.01861	.6038	.6768	.00	3.00
Total	2880	.6094	.71153	.01326	.5834	.6354	.00	3.00

ANOVA					
FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.750	1	2.750	5.441	.020
Within Groups	1454.797	2878	.505		
Total	1457.547	2879			

Chest feathers

Zone

Descriptives								
FEATHER SCORE								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Apron	960	.2958	.48112	.01553	.2654	.3263	.00	2.00
Enriched	960	.2115	.42605	.01375	.1845	.2384	.00	2.00
Outer range	960	.0698	.25899	.00836	.0534	.0862	.00	2.00
Total	2880	.1924	.41062	.00765	.1774	.2074	.00	2.00

ANOVA					
FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25.051	2	12.525	78.273	.000
Within Groups	460.381	2877	.160		
Total	485.432	2879			

Multiple Comparisons						
Dependent Variable: FEATHER SCORE						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	.08438*	.01826	.000	.0406	.1281

	Outer range	.22604*	.01826	.000	.1823	.2698
Enriched	Apron	-.08438*	.01826	.000	-.1281	-.0406
	Outer range	.14167*	.01826	.000	.0979	.1854
Outer range	Apron	-.22604*	.01826	.000	-.2698	-.1823
	Enriched	-.14167*	.01826	.000	-.1854	-.0979

*. The mean difference is significant at the 0.05 level.

Strain

Descriptives

FEATHER SCORE

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Hyline	1440	.1535	.37567	.00990	.1341	.1729	.00	2.00
Lohmann Brown	1440	.2313	.43953	.01158	.2085	.2540	.00	2.00
Total	2880	.1924	.41062	.00765	.1774	.2074	.00	2.00

ANOVA

FEATHER SCORE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.356	1	4.356	26.057	.000
Within Groups	481.076	2878	.167		
Total	485.432	2879			

Side feathers

Zone

FEATHER SCORE * Outdoor zones

FEATHER SCORE

Outdoor zones	Mean	N	Std. Deviation	Std. Error of Mean
Apron	.0063	960	.07885	.00254
Enriched	.0021	960	.04562	.00147
Outer range	.0000	960	.00000	.00000
Total	.0028	2880	.05264	.00098

ANOVA					
FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.019	2	.010	3.515	.030
Within Groups	7.958	2877	.003		
Total	7.978	2879			

Multiple Comparisons						
Dependent Variable: FEATHER SCORE						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	.00417	.00240	.248	-.0016	.0099
	Outer range	.00625*	.00240	.028	.0005	.0120
Enriched	Apron	-.00417	.00240	.248	-.0099	.0016
	Outer range	.00208	.00240	1.000	-.0037	.0078
Outer range	Apron	-.00625*	.00240	.028	-.0120	-.0005
	Enriched	-.00208	.00240	1.000	-.0078	.0037
*. The mean difference is significant at the 0.05 level.						

Strain

FEATHER SCORE * Strain of Flock				
FEATHER SCORE				
Strain of Flock	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	.0014	1440	.03725	.00098
Lohmann Brown	.0042	1440	.06444	.00170
Total	.0028	2880	.05264	.00098

ANOVA

FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.006	1	.006	2.006	.157
Within Groups	7.972	2878	.003		
Total	7.978	2879			

Back feathers

Zone

FEATHER SCORE * Outdoor zones				
FEATHER SCORE				
Outdoor zones	Mean	N	Std. Deviation	Std. Error of Mean
Apron	.2133	960	.42955	.01386
Enriched	.0135	960	.11564	.00373
Outer range	.0073	960	.08512	.00275
Total	.0781	2880	.27837	.00519

ANOVA					
FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.371	2	13.185	192.833	.000
Within Groups	196.722	2877	.068		
Total	223.093	2879			

Multiple Comparisons						
Dependent Variable: FEATHER SCORE						
Bonferroni						
(I) Outdoor zones	(J) Outdoor zones	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Apron	Enriched	.19979*	.01194	.000	.1712	.2284
	Outer range	.20604*	.01194	.000	.1775	.2346
Enriched	Apron	-.19979*	.01194	.000	-.2284	-.1712
	Outer range	.00625	.01194	1.000	-.0223	.0348
Outer range	Apron	-.20604*	.01194	.000	-.2346	-.1775
	Enriched	-.00625	.01194	1.000	-.0348	.0223
*. The mean difference is significant at the 0.05 level.						

Strain

FEATHER SCORE * Strain of Flock				
FEATHER SCORE				
Strain of Flock	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	.0604	1440	.24973	.00658
Lohmann Brown	.0957	1440	.30339	.00800
Total	.0781	2880	.27837	.00519

ANOVA					
FEATHER SCORE					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.896	1	.896	11.606	.001
Within Groups	222.197	2878	.077		
Total	223.093	2879			

Zone x body part

Apron

ANOVA					
featherscore					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	615.275	3	205.092	995.838	.000
Within Groups	790.019	3836	.206		
Total	1405.294	3839			

Multiple Comparisons						
Dependent Variable: featherscore						
Bonferroni						
(I) Feather score of body part	(J) Feather score of body part	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
neck	chest	.76771*	.02071	.000	.7130	.8224
	side	1.05729*	.02071	.000	1.0026	1.1120

	back	.85021*	.02071	.000	.7955	.9049
chest	neck	-.76771*	.02071	.000	-.8224	-.7130
	side	.28958*	.02071	.000	.2349	.3443
	back	.08250*	.02071	.000	.0278	.1372
side	neck	-1.05729*	.02071	.000	-1.1120	-1.0026
	chest	-.28958*	.02071	.000	-.3443	-.2349
	back	-.20708*	.02071	.000	-.2618	-.1524
back	neck	-.85021*	.02071	.000	-.9049	-.7955
	chest	-.08250*	.02071	.000	-.1372	-.0278
	side	.20708*	.02071	.000	.1524	.2618

*. The mean difference is significant at the 0.05 level.

Enriched

ANOVA

featherscore

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	232.473	3	77.491	413.320	.000
Within Groups	719.190	3836	.187		
Total	951.663	3839			

Multiple Comparisons

Dependent Variable: featherscore

Bonferroni

(I) Feather score of body part	(J) Feather score of body part	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
neck	chest	.39896*	.01976	.000	.3468	.4511
	side	.60833*	.01976	.000	.5562	.6605
	back	.59688*	.01976	.000	.5447	.6490
chest	neck	-.39896*	.01976	.000	-.4511	-.3468
	side	.20938*	.01976	.000	.1572	.2615
	back	.19792*	.01976	.000	.1457	.2501
side	neck	-.60833*	.01976	.000	-.6605	-.5562
	chest	-.20938*	.01976	.000	-.2615	-.1572
	back	-.01146	.01976	1.000	-.0636	.0407

back	neck	-.59688*	.01976	.000	-.6490	-.5447
	chest	-.19792*	.01976	.000	-.2501	-.1457
	side	.01146	.01976	1.000	-.0407	.0636
*. The mean difference is significant at the 0.05 level.						

Outer range

ANOVA

featherscore

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.709	3	4.903	86.892	.000
Within Groups	216.456	3836	.056		
Total	231.166	3839			

Multiple Comparisons

Dependent Variable: featherscore

Bonferroni

(I) Feather score of body part	(J) Feather score of body part	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
neck	chest	.08438*	.01084	.000	.0558	.1130
	side	.15417*	.01084	.000	.1255	.1828
	back	.14688*	.01084	.000	.1183	.1755
chest	neck	-.08438*	.01084	.000	-.1130	-.0558
	side	.06979*	.01084	.000	.0412	.0984
	back	.06250*	.01084	.000	.0339	.0911
side	neck	-.15417*	.01084	.000	-.1828	-.1255
	chest	-.06979*	.01084	.000	-.0984	-.0412
	back	-.00729	.01084	1.000	-.0359	.0213
back	neck	-.14688*	.01084	.000	-.1755	-.1183
	chest	-.06250*	.01084	.000	-.0911	-.0339
	side	.00729	.01084	1.000	-.0213	.0359
*. The mean difference is significant at the 0.05 level.						

Behaviour model simplification processes

Descriptive for all the behaviours

Descriptive Statistics						
	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Proportion of resting	144	.00	75.00	27.5640	1.68603	20.23231
Proportion of Appetitive+Foraging	144	.00	95.00	42.7339	1.64028	19.68339
Proportion of Locomotion	144	.00	70.00	25.9868	1.08557	13.02686
Proportion of Comfort	144	.00	60.00	3.6806	.84489	10.13866
Proportion fo Aggression	144	.00	5.00	.0347	.03472	.41667
Valid N (listwise)	144					

Resting behaviour
Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31412.295[a]	14	2243.735	10.671	.000
Intercept	30.430	1	30.430	.145	.704
Zone	228.130	2	114.065	.542	.583
Strain	1238.288	1	1238.288	5.889	.017
PopHole	99.712	1	99.712	.474	.492
Age	486.089	1	486.089	2.312	.131
FlockSize	202.383	1	202.383	.963	.328
Zone * Strain	429.583	2	214.791	1.022	.363
Zone * PopHole	1675.495	2	837.748	3.984	.021
Zone * Age	66.593	2	33.297	.158	.854
Zone * FlockSize	317.659	2	158.830	.755	.472
Error	27124.235	129	210.265		
Total	167943.698	144			
Corrected Total	58536.530	143			
a. R Squared = .537 (Adjusted R Squared = .486)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31094.635[a]	12	2591.220	12.370	.000
Intercept	30.430	1	30.430	.145	.704
Zone	189.234	2	94.617	.452	.638
Strain	1238.288	1	1238.288	5.911	.016
PopHole	99.712	1	99.712	.476	.491
Age	486.089	1	486.089	2.320	.130
FlockSize	202.383	1	202.383	.966	.327
Zone * Strain	1729.405	2	864.702	4.128	.018
Zone * PopHole	1877.040	2	938.520	4.480	.013
Zone * Age	1138.428	2	569.214	2.717	.070
Error	27441.895	131	209.480		
Total	167943.698	144			
Corrected Total	58536.530	143			
a. R Squared = .531 (Adjusted R Squared = .488)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29956.208[a]	10	2995.621	13.940	.000
Intercept	30.430	1	30.430	.142	.707
Zone	22515.980	2	11257.990	52.390	.000
Strain	1238.288	1	1238.288	5.762	.018
PopHole	99.712	1	99.712	.464	.497
Age	486.089	1	486.089	2.262	.135
FlockSize	202.383	1	202.383	.942	.334
Zone * Strain	1518.798	2	759.399	3.534	.032
Zone * PopHole	1879.220	2	939.610	4.373	.014
Error	28580.322	133	214.890		
Total	167943.698	144			
Corrected Total	58536.530	143			
a. R Squared = .512 (Adjusted R Squared = .475)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29753.825[a]	9	3305.981	15.391	.000
Intercept	1841.926	1	1841.926	8.575	.004
Zone	22515.980	2	11257.990	52.412	.000
Strain	1464.781	1	1464.781	6.819	.010
PopHole	293.677	1	293.677	1.367	.244
Age	301.338	1	301.338	1.403	.238
Zone * Strain	1518.798	2	759.399	3.535	.032
Zone * PopHole	1879.220	2	939.610	4.374	.014
Error	28782.705	134	214.796		
Total	167943.698	144			
Corrected Total	58536.530	143			
a. R Squared = .508 (Adjusted R Squared = .475)					

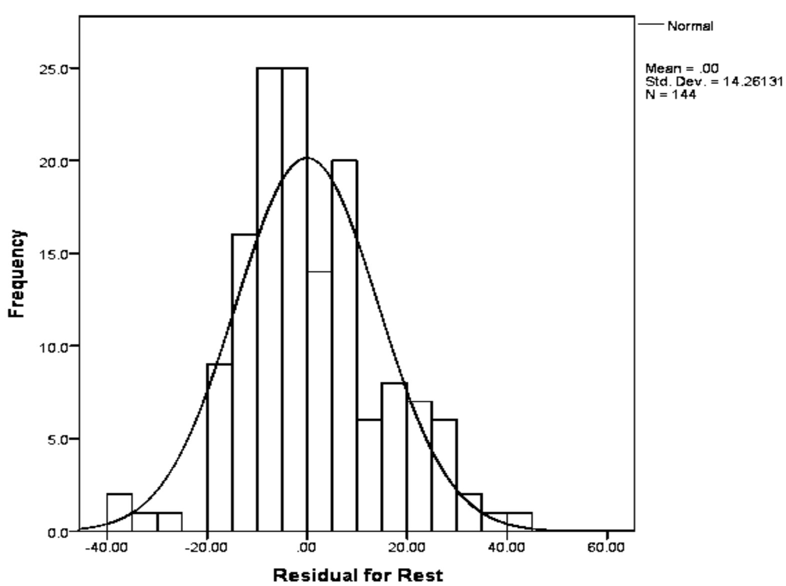
Step 5

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29452.487[a]	8	3681.561	17.089	.000
Intercept	92027.222	1	92027.222	427.165	.000
Zone	22515.980	2	11257.990	52.256	.000
Strain	1198.996	1	1198.996	5.565	.020
PopHole	282.181	1	282.181	1.310	.254
Zone * Strain	1518.798	2	759.399	3.525	.032
Zone * PopHole	1879.220	2	939.610	4.361	.015
Error	29084.043	135	215.437		
Total	167943.698	144			
Corrected Total	58536.530	143			
a. R Squared = .503 (Adjusted R Squared = .474)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29452.487[a]	8	3681.561	17.089	.000
Intercept	92027.222	1	92027.222	427.165	.000
Zone	22515.980	2	11257.990	52.256	.000
Strain	1198.996	1	1198.996	5.565	.020
Zone * Strain	1518.798	2	759.399	3.525	.032
Zone * PopHole	2161.401	3	720.467	3.344	.021
Error	29084.043	135	215.437		
Total	167943.698	144			
Corrected Total	58536.530	143			
a. R Squared = .503 (Adjusted R Squared = .474)					

Normal curve for residual



Main effects

Zone

Proportion of resting * Outdoor zone				
Proportion of resting				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	44.9287	48	19.44982	2.80734
Enriched	25.4167	48	13.75443	1.98528
Outer range	12.3465	48	11.34990	1.63822
Total	27.5640	144	20.23231	1.68603

Pairwise Comparisons						
Dependent Variable: Proportion of resting						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron	Enriched	23.643*	3.350	.000	15.523	31.763
	Outer range	33.276*	3.350	.000	25.155	41.396
Enriched	Apron	-23.643*	3.350	.000	-31.763	-15.523
	Outer range	9.633*	3.350	.014	1.512	17.753
Outer range	Apron	-33.276*	3.350	.000	-41.396	-25.155
	Enriched	-9.633*	3.350	.014	-17.753	-1.512
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Proportion of resting * Strain of hens				
Proportion of resting				
Strain of hens	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	30.2449	72	21.05802	2.48171
Lohmann Brown	24.8830	72	19.14264	2.25598
Total	27.5640	144	20.23231	1.68603

Pairwise Comparisons						
Dependent Variable: Proportion of resting						
(I) Strain of hens	(J) Strain of hens	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Hyline	Lohmann Brown	8.162*	3.460	.020	1.320	15.004
Lohmann Brown	Hyline	-8.162*	3.460	.020	-15.004	-1.320
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Zone X Strain

Proportion of resting * Strain of hens					
Proportion of resting					
Outdoor zone	Strain of hens	Mean	N	Std. Deviation	Std. Error of Mean
Apron	Hyline	50.0000	24	17.13121	3.49689
	Lohmann Brown	39.8575	24	20.63706	4.21252
	Total	44.9287	48	19.44982	2.80734
Enriched	Hyline	27.5000	24	14.06507	2.87102
	Lohmann Brown	23.3333	24	13.40560	2.73641
	Total	25.4167	48	13.75443	1.98528
Outer range	Hyline	13.2346	24	12.67096	2.58645
	Lohmann Brown	11.4583	24	10.05195	2.05185
	Total	12.3465	48	11.34990	1.63822

Strain X Zone

ANOVA						
Proportion of resting						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	1234.454	1	1234.454	3.432	.070

	Within Groups	16545.426	46	359.683		
	Total	17779.881	47			
Enriched	Between Groups	208.333	1	208.333	1.104	.299
	Within Groups	8683.333	46	188.768		
	Total	8891.667	47			
Outer range	Between Groups	37.864	1	37.864	.289	.593
	Within Groups	6016.684	46	130.797		
	Total	6054.548	47			

Zone X Strain

ANOVA						
Proportion of resting						
Strain of hens		Sum of Squares	df	Mean Square	F	Sig.
Hyline	Between Groups	16491.530	2	8245.765	37.949	.000
	Within Groups	14992.726	69	217.286		
	Total	31484.256	71			
Lohmann Brown	Between Groups	9764.579	2	4882.290	20.727	.000
	Within Groups	16252.718	69	235.547		
	Total	26017.298	71			

Multiple Comparisons							
Dependent Variable: Proportion of resting							
Bonferroni							
Strain of hens	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Hyline	Apron	Enriched	22.50000*	4.25525	.000	12.0587	32.9413
		Outer range	36.76535*	4.25525	.000	26.3241	47.2067
	Enriched	Apron	-22.50000*	4.25525	.000	-32.9413	-12.0587
		Outer range	14.26535*	4.25525	.004	3.8241	24.7067
	Outer range	Apron	-36.76535*	4.25525	.000	-47.2067	-26.3241
		Enriched	-14.26535*	4.25525	.004	-24.7067	-3.8241
Lohmann Brown	Apron	Enriched	16.52412*	4.43045	.001	5.6529	27.3953
		Outer range	28.39912*	4.43045	.000	17.5279	39.2703
	Enriched	Apron	-16.52412*	4.43045	.001	-27.3953	-5.6529

		Outer range	11.87500*	4.43045	.028	1.0038	22.7462
	Outer range	Apron	-28.39912*	4.43045	.000	-39.2703	-17.5279
		Enriched	-11.87500*	4.43045	.028	-22.7462	-1.0038
*. The mean difference is significant at the 0.05 level.							

Zone X Pop hole

Proportion of resting * Pop hole location					
Proportion of resting					
Outdoor zone	Pop hole location	Mean	N	Std. Deviation	Std. Error of Mean
Apron	One sided	44.4737	16	19.58008	4.89502
	Two sided	45.1563	32	19.69462	3.48155
	Total	44.9287	48	19.44982	2.80734
Enriched	One sided	19.6875	16	13.09819	3.27455
	Two sided	28.2813	32	13.35673	2.36116
	Total	25.4167	48	13.75443	1.98528
Outer range	One sided	14.6875	16	10.07782	2.51946
	Two sided	11.1760	32	11.91310	2.10596
	Total	12.3465	48	11.34990	1.63822

Pop hole X Zone

ANOVA						
Proportion of resting						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	4.970	1	4.970	.013	.910
	Within Groups	17774.911	46	386.411		
	Total	17779.881	47			
Enriched	Between Groups	787.760	1	787.760	4.472	.040
	Within Groups	8103.906	46	176.172		
	Total	8891.667	47			
Outer range	Between Groups	131.528	1	131.528	1.021	.317
	Within Groups	5923.020	46	128.761		
	Total	6054.548	47			

Zone X Pop hole

ANOVA						
Proportion of resting						
Pop hole location		Sum of Squares	df	Mean Square	F	Sig.
One sided	Between Groups	8141.716	2	4070.858	18.602	.000
	Within Groups	9847.568	45	218.835		
	Total	17989.283	47			
Two sided	Between Groups	18474.815	2	9237.408	39.130	.000
	Within Groups	21954.270	93	236.067		
	Total	40429.085	95			

Multiple Comparisons							
Dependent Variable: Proportion of resting							
Bonferroni							
Pop hole location	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
One sided	Apron	Enriched	24.78618*	5.23014	.000	11.7800	37.7924
		Outer range	29.78618*	5.23014	.000	16.7800	42.7924
	Enriched	Apron	-24.78618*	5.23014	.000	-37.7924	-11.7800
		Outer range	5.00000	5.23014	1.000	-8.0062	18.0062
	Outer range	Apron	-29.78618*	5.23014	.000	-42.7924	-16.7800
		Enriched	-5.00000	5.23014	1.000	-18.0062	8.0062
Two sided	Apron	Enriched	16.87500*	3.84112	.000	7.5101	26.2399
		Outer range	33.98026*	3.84112	.000	24.6154	43.3451
	Enriched	Apron	-16.87500*	3.84112	.000	-26.2399	-7.5101
		Outer range	17.10526*	3.84112	.000	7.7404	26.4701
	Outer range	Apron	-33.98026*	3.84112	.000	-43.3451	-24.6154
		Enriched	-17.10526*	3.84112	.000	-26.4701	-7.7404
*. The mean difference is significant at the 0.05 level.							

Appetitive/Foraging behaviour

Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Appetitive+Foraging					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20496.253[a]	14	1464.018	5.410	.000
Intercept	1934.570	1	1934.570	7.149	.008
Zone	95.085	2	47.543	.176	.839
Strain	964.545	1	964.545	3.565	.061
PopHole	122.233	1	122.233	.452	.503
Age	27.033	1	27.033	.100	.752
FlockSize	33.957	1	33.957	.125	.724
Zone * Strain	1369.288	2	684.644	2.530	.084
Zone * PopHole	1266.478	2	633.239	2.340	.100
Zone * Age	674.375	2	337.188	1.246	.291
Zone * FlockSize	174.971	2	87.485	.323	.724
Error	34907.087	129	270.598		
Total	318374.377	144			
Corrected Total	55403.339	143			
a. R Squared = .370 (Adjusted R Squared = .302)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Appetitive+Foraging					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20321.282[a]	12	1693.440	6.323	.000
Intercept	1934.570	1	1934.570	7.224	.008
Zone	2541.680	2	1270.840	4.745	.010
Strain	964.545	1	964.545	3.602	.060
PopHole	122.233	1	122.233	.456	.500
Age	27.033	1	27.033	.101	.751
FlockSize	33.957	1	33.957	.127	.722
Zone * Strain	1862.803	2	931.402	3.478	.034
Zone * PopHole	1979.555	2	989.777	3.696	.027
Zone * Age	2897.350	2	1448.675	5.410	.006

Error	35082.057	131	267.802		
Total	318374.377	144			
Corrected Total	55403.339	143			
a. R Squared = .367 (Adjusted R Squared = .309)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Appetitive+Foraging					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20287.325[a]	11	1844.302	6.933	.000
Intercept	8179.543	1	8179.543	30.747	.000
Zone	2541.680	2	1270.840	4.777	.010
Strain	1768.030	1	1768.030	6.646	.011
PopHole	213.884	1	213.884	.804	.372
Age	1.288	1	1.288	.005	.945
Zone * Strain	1862.803	2	931.402	3.501	.033
Zone * PopHole	1979.555	2	989.777	3.721	.027
Zone * Age	2897.350	2	1448.675	5.446	.005
Error	35116.014	132	266.030		
Total	318374.377	144			
Corrected Total	55403.339	143			
a. R Squared = .366 (Adjusted R Squared = .313)					

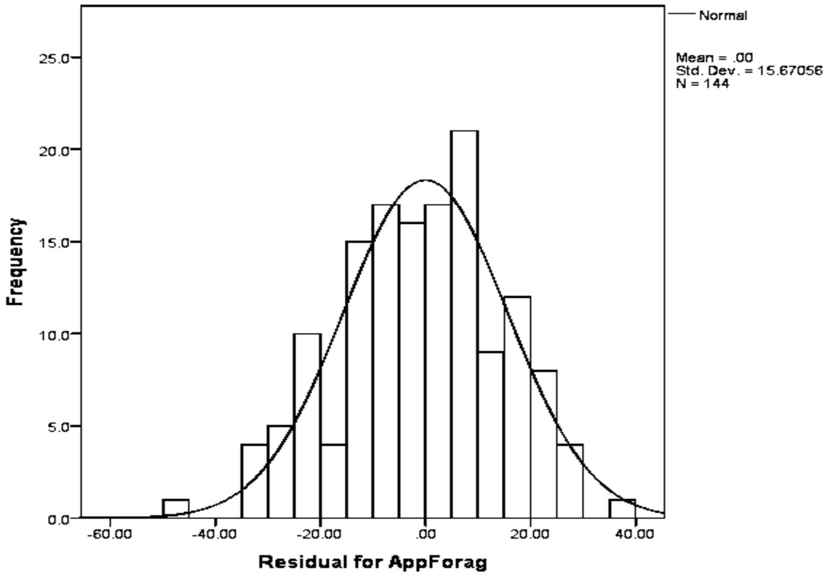
Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Appetitive+Foraging					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20287.325[a]	11	1844.302	6.933	.000
Intercept	8179.543	1	8179.543	30.747	.000
Zone	2541.680	2	1270.840	4.777	.010
Strain	1768.030	1	1768.030	6.646	.011
PopHole	213.884	1	213.884	.804	.372
Zone * Strain	1862.803	2	931.402	3.501	.033
Zone * PopHole	1979.555	2	989.777	3.721	.027

Zone * Age	2898.638	3	966.213	3.632	.015
Error	35116.014	132	266.030		
Total	318374.377	144			
Corrected Total	55403.339	143			
a. R Squared = .366 (Adjusted R Squared = .313)					

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Appetitive+Foraging					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20287.325[a]	11	1844.302	6.933	.000
Intercept	8179.543	1	8179.543	30.747	.000
Zone	2541.680	2	1270.840	4.777	.010
Strain	1768.030	1	1768.030	6.646	.011
Zone * Strain	1862.803	2	931.402	3.501	.033
Zone * PopHole	2193.439	3	731.146	2.748	.045
Zone * Age	2898.638	3	966.213	3.632	.015
Error	35116.014	132	266.030		
Total	318374.377	144			
Corrected Total	55403.339	143			
a. R Squared = .366 (Adjusted R Squared = .313)					

Normal curve for residual



Main effects

Zone

Proportion of Appetitive+Foraging * Outdoor zone				
Proportion of Appetitive+Foraging				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	30.1480	48	17.36375	2.50624
Enriched	48.0208	48	16.93981	2.44505
Outer range	50.0329	48	18.59054	2.68331
Total	42.7339	144	19.68339	1.64028

Pairwise Comparisons						
Dependent Variable: Proportion of Appetitive+Foraging						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron	Enriched	-21.172*	3.722	.000	-30.199	-12.146
	Outer range	-18.832*	3.722	.000	-27.858	-9.805
Enriched	Apron	21.172*	3.722	.000	12.146	30.199
	Outer range	2.341	3.722	1.000	-6.686	11.367
Outer range	Apron	18.832*	3.722	.000	9.805	27.858

	Enriched	-2.341	3.722	1.000	-11.367	6.686
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Strain

Proportion of Appetitive+Foraging * Strain of hens				
Proportion of Appetitive+Foraging				
Strain of hens	Mean	N	Std. Deviation	Std. Error of Mean
Hyline	38.7902	72	19.59455	2.30924
Lohmann Brown	46.6776	72	19.10074	2.25104
Total	42.7339	144	19.68339	1.64028

Pairwise Comparisons						
Dependent Variable: Proportion of Appetitive+Foraging						
(I) Strain of hens	(J) Strain of hens	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Hyline	Lohmann Brown	-10.407*	4.037	.011	-18.393	-2.422
Lohmann Brown	Hyline	10.407*	4.037	.011	2.422	18.393
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Interactions

Zone X Strain

Proportion of Appetitive+Foraging * Strain of hens					
Proportion of Appetitive+Foraging					
Outdoor zone	Strain of hens	Mean	N	Std. Deviation	Std. Error of Mean

Apron	Hyline	25.6250	24	15.90136	3.24585
	Lohmann Brown	34.6711	24	17.90420	3.65468
	Total	30.1480	48	17.36375	2.50624
Enriched	Hyline	48.1250	24	16.33964	3.33531
	Lohmann Brown	47.9167	24	17.87132	3.64797
	Total	48.0208	48	16.93981	2.44505
Outer range	Hyline	42.6206	24	19.44978	3.97017
	Lohmann Brown	57.4452	24	14.60436	2.98110
	Total	50.0329	48	18.59054	2.68331

Strain X Zone

ANOVA						
Proportion of Appetitive+Foraging						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	981.973	1	981.973	3.425	.071
	Within Groups	13188.513	46	286.707		
	Total	14170.486	47			
Enriched	Between Groups	.521	1	.521	.002	.967
	Within Groups	13486.458	46	293.184		
	Total	13486.979	47			
Outer range	Between Groups	2637.211	1	2637.211	8.916	.005
	Within Groups	13606.365	46	295.791		
	Total	16243.577	47			

Zone X Strain

ANOVA						
Proportion of Appetitive+Foraging						
Strain of hens		Sum of Squares	df	Mean Square	F	Sig.
Hyline	Between Groups	6603.193	2	3301.597	11.028	.000
	Within Groups	20657.009	69	299.377		
	Total	27260.202	71			
Lohmann Brown	Between Groups	6279.196	2	3139.598	11.039	.000
	Within Groups	19624.328	69	284.411		
	Total	25903.523	71			

Multiple Comparisons							
Dependent Variable: Proportion of Appetitive+Foraging							
Bonferroni							
Strain of hens	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Hyline	Apron	Enriched	-22.50000*	4.99481	.000	-34.7560	-10.2440
		Outer range	-16.99561*	4.99481	.003	-29.2516	-4.7396
	Enriched	Apron	22.50000*	4.99481	.000	10.2440	34.7560
		Outer range	5.50439	4.99481	.823	-6.7516	17.7604
	Outer range	Apron	16.99561*	4.99481	.003	4.7396	29.2516
		Enriched	-5.50439	4.99481	.823	-17.7604	6.7516
Lohmann Brown	Apron	Enriched	-13.24561*	4.86835	.025	-25.1913	-1.2999
		Outer range	-22.77412*	4.86835	.000	-34.7198	-10.8284
	Enriched	Apron	13.24561*	4.86835	.025	1.2999	25.1913
		Outer range	-9.52851	4.86835	.163	-21.4742	2.4172
	Outer range	Apron	22.77412*	4.86835	.000	10.8284	34.7198
		Enriched	9.52851	4.86835	.163	-2.4172	21.4742
*. The mean difference is significant at the 0.05 level.							

Zone X Pop hole location

Proportion of Appetitive+Foraging * Pop hole location					
Proportion of Appetitive+Foraging					
Outdoor zone	Pop hole location	Mean	N	Std. Deviation	Std. Error of Mean
Apron	One sided	32.0066	16	18.04091	4.51023
	Two sided	29.2188	32	17.23225	3.04626
	Total	30.1480	48	17.36375	2.50624
Enriched	One sided	51.8750	16	17.68945	4.42236
	Two sided	46.0938	32	16.49704	2.91629
	Total	48.0208	48	16.93981	2.44505
Outer range	One sided	52.5000	16	10.95445	2.73861
	Two sided	48.7993	32	21.47579	3.79642
	Total	50.0329	48	18.59054	2.68331

Pop hole X Zone

ANOVA

Proportion of Appetitive+Foraging						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	82.901	1	82.901	.271	.605
	Within Groups	14087.584	46	306.252		
	Total	14170.486	47			
Enriched	Between Groups	356.510	1	356.510	1.249	.270
	Within Groups	13130.469	46	285.445		
	Total	13486.979	47			
Outer range	Between Groups	146.079	1	146.079	.417	.521
	Within Groups	16097.498	46	349.946		
	Total	16243.577	47			

Zone X Pop hole

ANOVA						
Proportion of Appetitive+Foraging						
Pop hole location		Sum of Squares	df	Mean Square	F	Sig.
One sided	Between Groups	4347.334	2	2173.667	8.598	.001
	Within Groups	11375.866	45	252.797		
	Total	15723.199	47			
Two sided	Between Groups	7205.178	2	3602.589	10.490	.000
	Within Groups	31939.686	93	343.437		
	Total	39144.864	95			

Multiple Comparisons							
Dependent Variable: Proportion of Appetitive+Foraging							
Bonferroni							
Pop hole location	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
One sided	Apron	Enriched	-19.86842*	5.62135	.003	-33.8475	-5.8893
		Outer range	-20.49342*	5.62135	.002	-34.4725	-6.5143
	Enriched	Apron	19.86842*	5.62135	.003	5.8893	33.8475

		Outer range	-.62500	5.62135	1.000	-14.6041	13.3541
	Outer range	Apron	20.49342*	5.62135	.002	6.5143	34.4725
		Enriched	.62500	5.62135	1.000	-13.3541	14.6041
Two sided	Apron	Enriched	-16.87500*	4.63302	.001	-28.1705	-5.5795
		Outer range	-19.58059*	4.63302	.000	-30.8761	-8.2850
	Enriched	Apron	16.87500*	4.63302	.001	5.5795	28.1705
		Outer range	-2.70559	4.63302	1.000	-14.0011	8.5900
	Outer range	Apron	19.58059*	4.63302	.000	8.2850	30.8761
		Enriched	2.70559	4.63302	1.000	-8.5900	14.0011
*. The mean difference is significant at the 0.05 level.							

Zone X Age

Proportion of Appetitive+Foraging * Age of hens					
Proportion of Appetitive+Foraging					
Outdoor zone	Age of hens	Mean	N	Std. Deviation	Std. Error of Mean
Apron	27.00	32.5000	8	20.35401	7.19623
	48.00	16.8750	8	7.03943	2.48881
	49.00	33.1250	8	18.50434	6.54227
	51.00	40.0000	8	17.52549	6.19620
	52.00	30.8882	8	18.76633	6.63490
	55.00	27.5000	8	14.88048	5.26104
	Total	30.1480	48	17.36375	2.50624
Enriched	27.00	54.3750	8	21.28673	7.52600
	48.00	51.2500	8	11.25992	3.98098
	49.00	51.2500	8	20.65879	7.30399
	51.00	40.0000	8	16.47509	5.82482
	52.00	52.5000	8	15.58387	5.50973
	55.00	38.7500	8	11.87735	4.19928
	Total	48.0208	48	16.93981	2.44505
Outer range	27.00	30.7237	8	17.71903	6.26462
	48.00	44.3750	8	19.89930	7.03547
	49.00	54.3750	8	11.47591	4.05735
	51.00	67.3355	8	16.61229	5.87333
	52.00	50.6250	8	10.83562	3.83097
	55.00	52.7632	8	15.81702	5.59216
	Total	50.0329	48	18.59054	2.68331

Age X Zone

ANOVA						
Proportion of Appetitive+Foraging						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	2361.509	5	472.302	1.680	.161
	Within Groups	11808.977	42	281.166		
	Total	14170.486	47			
Enriched	Between Groups	1852.604	5	370.521	1.338	.267
	Within Groups	11634.375	42	277.009		
	Total	13486.979	47			
Outer range	Between Groups	5847.178	5	1169.436	4.724	.002
	Within Groups	10396.399	42	247.533		
	Total	16243.577	47			

Multiple Comparisons							
Dependent Variable: Proportion of Appetitive+Foraging							
Bonferroni							
Outdoor zone	(I) Age of hens	(J) Age of hens	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Apron	27.00	48.00	15.62500	8.38400	1.000	-10.4697	41.7197
		49.00	-.62500	8.38400	1.000	-26.7197	25.4697
		51.00	-7.50000	8.38400	1.000	-33.5947	18.5947
		52.00	1.61184	8.38400	1.000	-24.4828	27.7065
		55.00	5.00000	8.38400	1.000	-21.0947	31.0947
	48.00	27.00	-15.62500	8.38400	1.000	-41.7197	10.4697
		49.00	-16.25000	8.38400	.890	-42.3447	9.8447
		51.00	-23.12500	8.38400	.129	-49.2197	2.9697
		52.00	-14.01316	8.38400	1.000	-40.1078	12.0815
		55.00	-10.62500	8.38400	1.000	-36.7197	15.4697
	49.00	27.00	.62500	8.38400	1.000	-25.4697	26.7197
		48.00	16.25000	8.38400	.890	-9.8447	42.3447
		51.00	-6.87500	8.38400	1.000	-32.9697	19.2197
		52.00	2.23684	8.38400	1.000	-23.8578	28.3315
		55.00	5.62500	8.38400	1.000	-20.4697	31.7197

	51.00	27.00	7.50000	8.38400	1.000	-18.5947	33.5947
		48.00	23.12500	8.38400	.129	-2.9697	49.2197
		49.00	6.87500	8.38400	1.000	-19.2197	32.9697
		52.00	9.11184	8.38400	1.000	-16.9828	35.2065
		55.00	12.50000	8.38400	1.000	-13.5947	38.5947
	52.00	27.00	-1.61184	8.38400	1.000	-27.7065	24.4828
		48.00	14.01316	8.38400	1.000	-12.0815	40.1078
		49.00	-2.23684	8.38400	1.000	-28.3315	23.8578
		51.00	-9.11184	8.38400	1.000	-35.2065	16.9828
		55.00	3.38816	8.38400	1.000	-22.7065	29.4828
	55.00	27.00	-5.00000	8.38400	1.000	-31.0947	21.0947
		48.00	10.62500	8.38400	1.000	-15.4697	36.7197
		49.00	-5.62500	8.38400	1.000	-31.7197	20.4697
		51.00	-12.50000	8.38400	1.000	-38.5947	13.5947
		52.00	-3.38816	8.38400	1.000	-29.4828	22.7065
Enriched	27.00	48.00	3.12500	8.32179	1.000	-22.7760	29.0260
		49.00	3.12500	8.32179	1.000	-22.7760	29.0260
		51.00	14.37500	8.32179	1.000	-11.5260	40.2760
		52.00	1.87500	8.32179	1.000	-24.0260	27.7760
		55.00	15.62500	8.32179	1.000	-10.2760	41.5260
	48.00	27.00	-3.12500	8.32179	1.000	-29.0260	22.7760
		49.00	.00000	8.32179	1.000	-25.9010	25.9010
		51.00	11.25000	8.32179	1.000	-14.6510	37.1510
		52.00	-1.25000	8.32179	1.000	-27.1510	24.6510
		55.00	12.50000	8.32179	1.000	-13.4010	38.4010
	49.00	27.00	-3.12500	8.32179	1.000	-29.0260	22.7760
		48.00	.00000	8.32179	1.000	-25.9010	25.9010
		51.00	11.25000	8.32179	1.000	-14.6510	37.1510
		52.00	-1.25000	8.32179	1.000	-27.1510	24.6510
		55.00	12.50000	8.32179	1.000	-13.4010	38.4010
	51.00	27.00	-14.37500	8.32179	1.000	-40.2760	11.5260
		48.00	-11.25000	8.32179	1.000	-37.1510	14.6510
		49.00	-11.25000	8.32179	1.000	-37.1510	14.6510
		52.00	-12.50000	8.32179	1.000	-38.4010	13.4010
		55.00	1.25000	8.32179	1.000	-24.6510	27.1510
	52.00	27.00	-1.87500	8.32179	1.000	-27.7760	24.0260
		48.00	1.25000	8.32179	1.000	-24.6510	27.1510
		49.00	1.25000	8.32179	1.000	-24.6510	27.1510
		51.00	12.50000	8.32179	1.000	-13.4010	38.4010

		55.00	13.75000	8.32179	1.000	-12.1510	39.6510
	55.00	27.00	-15.62500	8.32179	1.000	-41.5260	10.2760
		48.00	-12.50000	8.32179	1.000	-38.4010	13.4010
		49.00	-12.50000	8.32179	1.000	-38.4010	13.4010
		51.00	-1.25000	8.32179	1.000	-27.1510	24.6510
		52.00	-13.75000	8.32179	1.000	-39.6510	12.1510
Outer range	27.00	48.00	-13.65132	7.86660	1.000	-38.1356	10.8330
		49.00	-23.65132	7.86660	.067	-48.1356	.8330
		51.00	-36.61184*	7.86660	.000	-61.0961	-12.1276
		52.00	-19.90132	7.86660	.229	-44.3856	4.5830
		55.00	-22.03947	7.86660	.115	-46.5237	2.4448
	48.00	27.00	13.65132	7.86660	1.000	-10.8330	38.1356
		49.00	-10.00000	7.86660	1.000	-34.4843	14.4843
		51.00	-22.96053	7.86660	.084	-47.4448	1.5237
		52.00	-6.25000	7.86660	1.000	-30.7343	18.2343
		55.00	-8.38816	7.86660	1.000	-32.8724	16.0961
	49.00	27.00	23.65132	7.86660	.067	-.8330	48.1356
		48.00	10.00000	7.86660	1.000	-14.4843	34.4843
		51.00	-12.96053	7.86660	1.000	-37.4448	11.5237
		52.00	3.75000	7.86660	1.000	-20.7343	28.2343
		55.00	1.61184	7.86660	1.000	-22.8724	26.0961
	51.00	27.00	36.61184*	7.86660	.000	12.1276	61.0961
		48.00	22.96053	7.86660	.084	-1.5237	47.4448
		49.00	12.96053	7.86660	1.000	-11.5237	37.4448
		52.00	16.71053	7.86660	.594	-7.7737	41.1948
		55.00	14.57237	7.86660	1.000	-9.9119	39.0566
	52.00	27.00	19.90132	7.86660	.229	-4.5830	44.3856
		48.00	6.25000	7.86660	1.000	-18.2343	30.7343
		49.00	-3.75000	7.86660	1.000	-28.2343	20.7343
		51.00	-16.71053	7.86660	.594	-41.1948	7.7737
		55.00	-2.13816	7.86660	1.000	-26.6224	22.3461
	55.00	27.00	22.03947	7.86660	.115	-2.4448	46.5237
		48.00	8.38816	7.86660	1.000	-16.0961	32.8724
		49.00	-1.61184	7.86660	1.000	-26.0961	22.8724
		51.00	-14.57237	7.86660	1.000	-39.0566	9.9119
		52.00	2.13816	7.86660	1.000	-22.3461	26.6224

*. The mean difference is significant at the 0.05 level.

Zone X Age

ANOVA						
Proportion of Appetitive+Foraging						
Age of hens		Sum of Squares	df	Mean Square	F	Sig.
27.00	Between Groups	2776.148	2	1388.074	3.525	.048
	Within Groups	8269.624	21	393.792		
	Total	11045.773	23			
48.00	Between Groups	5293.750	2	2646.875	13.874	.000
	Within Groups	4006.250	21	190.774		
	Total	9300.000	23			
49.00	Between Groups	2106.250	2	1053.125	3.507	.049
	Within Groups	6306.250	21	300.298		
	Total	8412.500	23			
51.00	Between Groups	3985.232	2	1992.616	6.995	.005
	Within Groups	5981.778	21	284.847		
	Total	9967.010	23			
52.00	Between Groups	2293.681	2	1146.840	4.829	.019
	Within Groups	4987.102	21	237.481		
	Total	7280.783	23			
55.00	Between Groups	2563.089	2	1281.544	6.275	.007
	Within Groups	4288.747	21	204.226		
	Total	6851.835	23			

Multiple Comparisons							
Dependent Variable: Proportion of Appetitive+Foraging							
Bonferroni							
Age of hens	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
27.00	Apron	Enriched	-21.87500	9.92209	.116	-47.6858	3.9358
		Outer range	1.77632	9.92209	1.000	-24.0345	27.5871
	Enriched	Apron	21.87500	9.92209	.116	-3.9358	47.6858
		Outer range	23.65132	9.92209	.080	-2.1595	49.4621
	Outer range	Apron	-1.77632	9.92209	1.000	-27.5871	24.0345
		Enriched	-23.65132	9.92209	.080	-49.4621	2.1595
48.00	Apron	Enriched	-34.37500*	6.90604	.000	-52.3400	-16.4100
		Outer range	-27.50000*	6.90604	.002	-45.4650	-9.5350

	Enriched	Apron	34.37500*	6.90604	.000	16.4100	52.3400
		Outer range	6.87500	6.90604	.992	-11.0900	24.8400
	Outer range	Apron	27.50000*	6.90604	.002	9.5350	45.4650
		Enriched	-6.87500	6.90604	.992	-24.8400	11.0900
49.00	Apron	Enriched	-18.12500	8.66455	.146	-40.6645	4.4145
		Outer range	-21.25000	8.66455	.069	-43.7895	1.2895
	Enriched	Apron	18.12500	8.66455	.146	-4.4145	40.6645
		Outer range	-3.12500	8.66455	1.000	-25.6645	19.4145
	Outer range	Apron	21.25000	8.66455	.069	-1.2895	43.7895
		Enriched	3.12500	8.66455	1.000	-19.4145	25.6645
51.00	Apron	Enriched	.00000	8.43870	1.000	-21.9520	21.9520
		Outer range	-27.33553*	8.43870	.012	-49.2875	-5.3835
	Enriched	Apron	.00000	8.43870	1.000	-21.9520	21.9520
		Outer range	-27.33553*	8.43870	.012	-49.2875	-5.3835
	Outer range	Apron	27.33553*	8.43870	.012	5.3835	49.2875
		Enriched	27.33553*	8.43870	.012	5.3835	49.2875
52.00	Apron	Enriched	-21.61184*	7.70521	.032	-41.6558	-1.5679
		Outer range	-19.73684	7.70521	.055	-39.7808	.3071
	Enriched	Apron	21.61184*	7.70521	.032	1.5679	41.6558
		Outer range	1.87500	7.70521	1.000	-18.1689	21.9189
	Outer range	Apron	19.73684	7.70521	.055	-.3071	39.7808
		Enriched	-1.87500	7.70521	1.000	-21.9189	18.1689
55.00	Apron	Enriched	-11.25000	7.14538	.391	-29.8376	7.3376
		Outer range	-25.26316*	7.14538	.006	-43.8508	-6.6755
	Enriched	Apron	11.25000	7.14538	.391	-7.3376	29.8376
		Outer range	-14.01316	7.14538	.190	-32.6008	4.5745
	Outer range	Apron	25.26316*	7.14538	.006	6.6755	43.8508
		Enriched	14.01316	7.14538	.190	-4.5745	32.6008

*. The mean difference is significant at the 0.05 level.

Locomotion

Step 1

Tests of Between-Subjects Effects

Dependent Variable: Proportion of Locomotion

Source	Type III Sum of Squares	df	Mean Square	F	Sig.

Corrected Model	7510.120[a]	14	536.437	4.130	.000
Intercept	614.787	1	614.787	4.733	.031
Zone	718.334	2	359.167	2.765	.067
Strain	17.121	1	17.121	.132	.717
PopHole	11.390	1	11.390	.088	.768
Age	9.202	1	9.202	.071	.791
FlockSize	5.791	1	5.791	.045	.833
Zone * Strain	163.708	2	81.854	.630	.534
Zone * PopHole	982.479	2	491.239	3.782	.025
Zone * Age	605.257	2	302.628	2.330	.101
Zone * FlockSize	270.545	2	135.272	1.041	.356
Error	16756.847	129	129.898		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .309 (Adjusted R Squared = .235)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7239.575[a]	12	603.298	4.641	.000
Intercept	614.787	1	614.787	4.730	.031
Zone	1509.109	2	754.554	5.805	.004
Strain	17.121	1	17.121	.132	.717
PopHole	11.390	1	11.390	.088	.768
Age	9.202	1	9.202	.071	.791
FlockSize	5.791	1	5.791	.045	.833
Zone * Strain	1498.064	2	749.032	5.763	.004
Zone * PopHole	736.609	2	368.305	2.834	.062
Zone * Age	863.731	2	431.865	3.323	.039
Error	17027.392	131	129.980		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .298 (Adjusted R Squared = .234)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6502.966[a]	10	650.297	4.869	.000
Intercept	614.787	1	614.787	4.603	.034
Zone	1428.593	2	714.296	5.348	.006
Strain	17.121	1	17.121	.128	.721
PopHole	11.390	1	11.390	.085	.771
Age	9.202	1	9.202	.069	.793
FlockSize	5.791	1	5.791	.043	.835
Zone * Strain	772.930	2	386.465	2.893	.059
Zone * Age	876.686	2	438.343	3.282	.041
Error	17764.001	133	133.564		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .268 (Adjusted R Squared = .213)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5730.036[a]	8	716.254	5.216	.000
Intercept	614.787	1	614.787	4.477	.036
Zone	2524.866	2	1262.433	9.194	.000
Strain	17.121	1	17.121	.125	.725
PopHole	11.390	1	11.390	.083	.774
Age	9.202	1	9.202	.067	.796
FlockSize	5.791	1	5.791	.042	.838
Zone * Age	1616.916	2	808.458	5.888	.004
Error	18536.931	135	137.311		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .236 (Adjusted R Squared = .191)					

Step 5

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5724.245[a]	7	817.749	5.998	.000
Intercept	3968.861	1	3968.861	29.109	.000
Zone	2524.866	2	1262.433	9.259	.000
Strain	12.950	1	12.950	.095	.758
PopHole	22.462	1	22.462	.165	.685
Age	57.924	1	57.924	.425	.516
Zone * Age	1616.916	2	808.458	5.930	.003
Error	18542.722	136	136.344		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .236 (Adjusted R Squared = .197)					

Step 6

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5724.245[a]	7	817.749	5.998	.000
Intercept	3968.861	1	3968.861	29.109	.000
Zone	2524.866	2	1262.433	9.259	.000
Strain	12.950	1	12.950	.095	.758
PopHole	22.462	1	22.462	.165	.685
Zone * Age	1674.840	3	558.280	4.095	.008
Error	18542.722	136	136.344		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .236 (Adjusted R Squared = .197)					

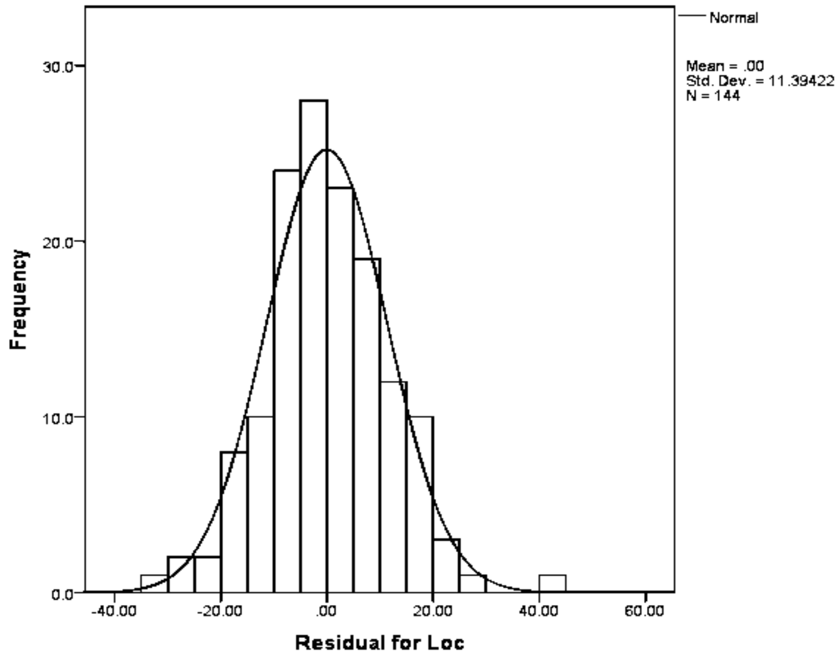
Step 7

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5701.783[a]	6	950.297	7.013	.000
Intercept	3946.553	1	3946.553	29.123	.000
Zone	2524.866	2	1262.433	9.316	.000
Strain	.267	1	.267	.002	.965
Zone * Age	1676.293	3	558.764	4.123	.008
Error	18565.184	137	135.512		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .235 (Adjusted R Squared = .201)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Locomotion					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5701.515[a]	5	1140.303	8.476	.000
Intercept	4690.658	1	4690.658	34.866	.000
Zone	2524.866	2	1262.433	9.384	.000
Zone * Age	1691.263	3	563.754	4.190	.007
Error	18565.451	138	134.532		
Total	121512.465	144			
Corrected Total	24266.967	143			
a. R Squared = .235 (Adjusted R Squared = .207)					

Normal curve for residuals



Main effects

Zone

Report				
Proportion of locomotive behaviour				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	33.1170	2843	23.06653	.43261
Enriched	34.7800	2576	24.30829	.47894
Outer range	45.8213	1378	32.35379	.87157
Total	36.3229	6797	26.11480	.31676

Pairwise Comparisons						
Dependent Variable: Proportion of Locomotion						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron	Enriched	2.111	2.368	1.000	-3.627	7.849
	Outer range	-9.989*	2.368	.000	-15.727	-4.251
Enriched	Apron	-2.111	2.368	1.000	-7.849	3.627

	Outer range	-12.100*	2.368	.000	-17.838	-6.362
Outer range	Apron	9.989*	2.368	.000	4.251	15.727
	Enriched	12.100*	2.368	.000	6.362	17.838
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Interaction

Zone X Age

Descriptives									
Proportion of Locomotion									
Outdoor zone		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Apron	27.00	8	26.8750	9.97765	3.52763	18.5335	35.2165	15.00	45.00
	48.00	8	21.8750	10.32940	3.65199	13.2394	30.5106	5.00	40.00
	49.00	8	20.0000	10.35098	3.65963	11.3464	28.6536	5.00	40.00
	51.00	8	27.5000	14.14214	5.00000	15.6769	39.3231	10.00	50.00
	52.00	8	25.1645	8.87625	3.13823	17.7437	32.5852	15.00	40.00
	55.00	8	18.7500	5.82482	2.05939	13.8803	23.6197	10.00	25.00
	Total	48	23.3607	10.23422	1.47718	20.3890	26.3325	5.00	50.00
Enriched	27.00	8	14.3750	9.79705	3.46378	6.1845	22.5655	.00	25.00
	48.00	8	14.3750	10.50085	3.71261	5.5961	23.1539	.00	35.00
	49.00	8	21.8750	12.22921	4.32368	11.6511	32.0989	5.00	40.00
	51.00	8	25.6250	4.17261	1.47524	22.1366	29.1134	20.00	30.00
	52.00	8	25.0000	7.55929	2.67261	18.6803	31.3197	15.00	40.00
	55.00	8	26.2500	7.90569	2.79508	19.6407	32.8593	15.00	40.00
	Total	48	21.2500	9.97337	1.43953	18.3540	24.1460	.00	40.00
Outer range	27.00	8	44.6053	12.19077	4.31009	34.4135	54.7970	25.00	60.00
	48.00	8	29.3750	17.61442	6.22764	14.6490	44.1010	.00	55.00
	49.00	8	35.0000	10.35098	3.65963	26.3464	43.6536	15.00	45.00
	51.00	8	21.4145	12.81117	4.52943	10.7041	32.1249	5.00	40.00
	52.00	8	29.3750	12.37437	4.37500	19.0298	39.7202	10.00	50.00
	55.00	8	40.3289	15.39337	5.44238	27.4598	53.1981	25.00	70.00
	Total	48	33.3498	15.05943	2.17364	28.9770	37.7226	.00	70.00

Age X Zone

ANOVA						
Proportion of Locomotion						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	539.983	5	107.997	1.035	.410
	Within Groups	4382.765	42	104.352		
	Total	4922.748	47			
Enriched	Between Groups	1225.000	5	245.000	2.983	.022
	Within Groups	3450.000	42	82.143		
	Total	4675.000	47			
Outer range	Between Groups	2817.338	5	563.468	3.018	.020
	Within Groups	7841.629	42	186.705		
	Total	10658.967	47			

Multiple Comparisons							
Dependent Variable: Proportion of Locomotion							
Bonferroni							
Outdoor zone	(I) Age of hens	(J) Age of hens	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Apron	27.00	48.00	5.00000	5.10763	1.000	-10.8972	20.8972
		49.00	6.87500	5.10763	1.000	-9.0222	22.7722
		51.00	-.62500	5.10763	1.000	-16.5222	15.2722
		52.00	1.71053	5.10763	1.000	-14.1866	17.6077
		55.00	8.12500	5.10763	1.000	-7.7722	24.0222
	48.00	27.00	-5.00000	5.10763	1.000	-20.8972	10.8972
		49.00	1.87500	5.10763	1.000	-14.0222	17.7722
		51.00	-5.62500	5.10763	1.000	-21.5222	10.2722
		52.00	-3.28947	5.10763	1.000	-19.1866	12.6077
		55.00	3.12500	5.10763	1.000	-12.7722	19.0222
	49.00	27.00	-6.87500	5.10763	1.000	-22.7722	9.0222
		48.00	-1.87500	5.10763	1.000	-17.7722	14.0222
		51.00	-7.50000	5.10763	1.000	-23.3972	8.3972

		52.00	-5.16447	5.10763	1.000	-21.0616	10.7327
		55.00	1.25000	5.10763	1.000	-14.6472	17.1472
	51.00	27.00	.62500	5.10763	1.000	-15.2722	16.5222
		48.00	5.62500	5.10763	1.000	-10.2722	21.5222
		49.00	7.50000	5.10763	1.000	-8.3972	23.3972
		52.00	2.33553	5.10763	1.000	-13.5616	18.2327
		55.00	8.75000	5.10763	1.000	-7.1472	24.6472
	52.00	27.00	-1.71053	5.10763	1.000	-17.6077	14.1866
		48.00	3.28947	5.10763	1.000	-12.6077	19.1866
		49.00	5.16447	5.10763	1.000	-10.7327	21.0616
		51.00	-2.33553	5.10763	1.000	-18.2327	13.5616
		55.00	6.41447	5.10763	1.000	-9.4827	22.3116
	55.00	27.00	-8.12500	5.10763	1.000	-24.0222	7.7722
		48.00	-3.12500	5.10763	1.000	-19.0222	12.7722
		49.00	-1.25000	5.10763	1.000	-17.1472	14.6472
		51.00	-8.75000	5.10763	1.000	-24.6472	7.1472
		52.00	-6.41447	5.10763	1.000	-22.3116	9.4827
Enriched	27.00	48.00	.00000	4.53163	1.000	-14.1044	14.1044
		49.00	-7.50000	4.53163	1.000	-21.6044	6.6044
		51.00	-11.25000	4.53163	.257	-25.3544	2.8544
		52.00	-10.62500	4.53163	.358	-24.7294	3.4794
		55.00	-11.87500	4.53163	.183	-25.9794	2.2294
	48.00	27.00	.00000	4.53163	1.000	-14.1044	14.1044
		49.00	-7.50000	4.53163	1.000	-21.6044	6.6044
		51.00	-11.25000	4.53163	.257	-25.3544	2.8544
		52.00	-10.62500	4.53163	.358	-24.7294	3.4794
		55.00	-11.87500	4.53163	.183	-25.9794	2.2294
	49.00	27.00	7.50000	4.53163	1.000	-6.6044	21.6044
		48.00	7.50000	4.53163	1.000	-6.6044	21.6044
		51.00	-3.75000	4.53163	1.000	-17.8544	10.3544
		52.00	-3.12500	4.53163	1.000	-17.2294	10.9794
		55.00	-4.37500	4.53163	1.000	-18.4794	9.7294
	51.00	27.00	11.25000	4.53163	.257	-2.8544	25.3544
		48.00	11.25000	4.53163	.257	-2.8544	25.3544
		49.00	3.75000	4.53163	1.000	-10.3544	17.8544
		52.00	.62500	4.53163	1.000	-13.4794	14.7294
		55.00	-.62500	4.53163	1.000	-14.7294	13.4794
	52.00	27.00	10.62500	4.53163	.358	-3.4794	24.7294
		48.00	10.62500	4.53163	.358	-3.4794	24.7294

		49.00	3.12500	4.53163	1.000	-10.9794	17.2294
		51.00	-.62500	4.53163	1.000	-14.7294	13.4794
		55.00	-1.25000	4.53163	1.000	-15.3544	12.8544
	55.00	27.00	11.87500	4.53163	.183	-2.2294	25.9794
		48.00	11.87500	4.53163	.183	-2.2294	25.9794
		49.00	4.37500	4.53163	1.000	-9.7294	18.4794
		51.00	.62500	4.53163	1.000	-13.4794	14.7294
		52.00	1.25000	4.53163	1.000	-12.8544	15.3544
Outer range	27.00	48.00	15.23026	6.83201	.468	-6.0339	36.4945
		49.00	9.60526	6.83201	1.000	-11.6589	30.8695
		51.00	23.19079*	6.83201	.023	1.9266	44.4550
		52.00	15.23026	6.83201	.468	-6.0339	36.4945
		55.00	4.27632	6.83201	1.000	-16.9879	25.5405
	48.00	27.00	-15.23026	6.83201	.468	-36.4945	6.0339
		49.00	-5.62500	6.83201	1.000	-26.8892	15.6392
		51.00	7.96053	6.83201	1.000	-13.3037	29.2247
		52.00	.00000	6.83201	1.000	-21.2642	21.2642
		55.00	-10.95395	6.83201	1.000	-32.2181	10.3102
	49.00	27.00	-9.60526	6.83201	1.000	-30.8695	11.6589
		48.00	5.62500	6.83201	1.000	-15.6392	26.8892
		51.00	13.58553	6.83201	.799	-7.6787	34.8497
		52.00	5.62500	6.83201	1.000	-15.6392	26.8892
		55.00	-5.32895	6.83201	1.000	-26.5931	15.9352
	51.00	27.00	-23.19079*	6.83201	.023	-44.4550	-1.9266
		48.00	-7.96053	6.83201	1.000	-29.2247	13.3037
		49.00	-13.58553	6.83201	.799	-34.8497	7.6787
		52.00	-7.96053	6.83201	1.000	-29.2247	13.3037
		55.00	-18.91447	6.83201	.125	-40.1787	2.3497
	52.00	27.00	-15.23026	6.83201	.468	-36.4945	6.0339
		48.00	.00000	6.83201	1.000	-21.2642	21.2642
		49.00	-5.62500	6.83201	1.000	-26.8892	15.6392
		51.00	7.96053	6.83201	1.000	-13.3037	29.2247
		55.00	-10.95395	6.83201	1.000	-32.2181	10.3102
	55.00	27.00	-4.27632	6.83201	1.000	-25.5405	16.9879
		48.00	10.95395	6.83201	1.000	-10.3102	32.2181
		49.00	5.32895	6.83201	1.000	-15.9352	26.5931
		51.00	18.91447	6.83201	.125	-2.3497	40.1787
		52.00	10.95395	6.83201	1.000	-10.3102	32.2181

*. The mean difference is significant at the 0.05 level.

Zone X Age

ANOVA						
Proportion of Locomotion						
Age of hens		Sum of Squares	df	Mean Square	F	Sig.
27.00	Between Groups	3691.949	2	1845.975	16.092	.000
	Within Groups	2409.055	21	114.717		
	Total	6101.004	23			
48.00	Between Groups	900.000	2	450.000	2.561	.101
	Within Groups	3690.625	21	175.744		
	Total	4590.625	23			
49.00	Between Groups	1068.750	2	534.375	4.406	.025
	Within Groups	2546.875	21	121.280		
	Total	3615.625	23			
51.00	Between Groups	155.407	2	77.704	.611	.552
	Within Groups	2670.758	21	127.179		
	Total	2826.166	23			
52.00	Between Groups	98.390	2	49.195	.511	.607
	Within Groups	2023.390	21	96.352		
	Total	2121.780	23			
55.00	Between Groups	1920.314	2	960.157	8.640	.002
	Within Groups	2333.691	21	111.128		
	Total	4254.005	23			

Multiple Comparisons							
Dependent Variable: Proportion of Locomotion							
Bonferroni							
Age of hens	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
27.00	Apron	Enriched	12.50000	5.35530	.089	-1.4310	26.4310
		Outer range	-17.73026*	5.35530	.010	-31.6613	-3.7993
	Enriched	Apron	-12.50000	5.35530	.089	-26.4310	1.4310
		Outer range	-30.23026*	5.35530	.000	-44.1613	-16.2993

	Outer range	Apron	17.73026*	5.35530	.010	3.7993	31.6613
		Enriched	30.23026*	5.35530	.000	16.2993	44.1613
48.00	Apron	Enriched	7.50000	6.62842	.812	-9.7429	24.7429
		Outer range	-7.50000	6.62842	.812	-24.7429	9.7429
	Enriched	Apron	-7.50000	6.62842	.812	-24.7429	9.7429
		Outer range	-15.00000	6.62842	.103	-32.2429	2.2429
	Outer range	Apron	7.50000	6.62842	.812	-9.7429	24.7429
		Enriched	15.00000	6.62842	.103	-2.2429	32.2429
49.00	Apron	Enriched	-1.87500	5.50635	1.000	-16.1990	12.4490
		Outer range	-15.00000*	5.50635	.038	-29.3240	-.6760
	Enriched	Apron	1.87500	5.50635	1.000	-12.4490	16.1990
		Outer range	-13.12500	5.50635	.080	-27.4490	1.1990
	Outer range	Apron	15.00000*	5.50635	.038	.6760	29.3240
		Enriched	13.12500	5.50635	.080	-1.1990	27.4490
51.00	Apron	Enriched	1.87500	5.63868	1.000	-12.7932	16.5432
		Outer range	6.08553	5.63868	.878	-8.5827	20.7537
	Enriched	Apron	-1.87500	5.63868	1.000	-16.5432	12.7932
		Outer range	4.21053	5.63868	1.000	-10.4577	18.8787
	Outer range	Apron	-6.08553	5.63868	.878	-20.7537	8.5827
		Enriched	-4.21053	5.63868	1.000	-18.8787	10.4577
52.00	Apron	Enriched	.16447	4.90795	1.000	-12.6028	12.9318
		Outer range	-4.21053	4.90795	1.000	-16.9778	8.5568
	Enriched	Apron	-.16447	4.90795	1.000	-12.9318	12.6028
		Outer range	-4.37500	4.90795	1.000	-17.1423	8.3923
	Outer range	Apron	4.21053	4.90795	1.000	-8.5568	16.9778
		Enriched	4.37500	4.90795	1.000	-8.3923	17.1423
55.00	Apron	Enriched	-7.50000	5.27087	.508	-21.2114	6.2114
		Outer range	-21.57895*	5.27087	.002	-35.2903	-7.8676
	Enriched	Apron	7.50000	5.27087	.508	-6.2114	21.2114
		Outer range	-14.07895*	5.27087	.043	-27.7903	-.3676
	Outer range	Apron	21.57895*	5.27087	.002	7.8676	35.2903
		Enriched	14.07895*	5.27087	.043	.3676	27.7903
*. The mean difference is significant at the 0.05 level.							

Comfort behaviour

Step 1

Tests of Between-Subjects Effects

Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1188.876[a]	14	84.920	.811	.656
Intercept	275.881	1	275.881	2.634	.107
Zone	201.577	2	100.788	.962	.385
Strain	71.997	1	71.997	.687	.409
PopHole	5.535	1	5.535	.053	.819
Age	199.129	1	199.129	1.901	.170
FlockSize	114.740	1	114.740	1.096	.297
Zone * Strain	58.220	2	29.110	.278	.758
Zone * PopHole	242.279	2	121.139	1.157	.318
Zone * Age	144.289	2	72.145	.689	.504
Zone * FlockSize	175.846	2	87.923	.840	.434
Error	13510.429	129	104.732		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .081 (Adjusted R Squared = -.019)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1013.031[a]	12	84.419	.808	.642
Intercept	275.881	1	275.881	2.641	.107
Zone	131.604	2	65.802	.630	.534
Strain	71.997	1	71.997	.689	.408
PopHole	5.535	1	5.535	.053	.818
Age	199.129	1	199.129	1.906	.170
FlockSize	114.740	1	114.740	1.098	.297
Zone * Strain	19.237	2	9.619	.092	.912
Zone * PopHole	132.734	2	66.367	.635	.531
Zone * Age	72.375	2	36.187	.346	.708
Error	13686.275	131	104.475		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .069 (Adjusted R Squared = -.016)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	940.656[a]	10	94.066	.909	.527
Intercept	275.881	1	275.881	2.667	.105
Zone	341.875	2	170.938	1.652	.195
Strain	71.997	1	71.997	.696	.406
PopHole	5.535	1	5.535	.054	.817
Age	199.129	1	199.129	1.925	.168
FlockSize	114.740	1	114.740	1.109	.294
Zone * Strain	25.000	2	12.500	.121	.886
Zone * PopHole	131.597	2	65.799	.636	.531
Error	13758.650	133	103.448		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .064 (Adjusted R Squared = -.006)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	809.059[a]	8	101.132	.983	.452
Intercept	275.881	1	275.881	2.681	.104
Zone	381.597	2	190.799	1.854	.161
Strain	71.997	1	71.997	.700	.404
PopHole	5.535	1	5.535	.054	.817
Age	199.129	1	199.129	1.935	.166
FlockSize	114.740	1	114.740	1.115	.293
Zone * Strain	60.764	2	30.382	.295	.745
Error	13890.247	135	102.891		
Total	16650.000	144			
Corrected Total	14699.306	143			

a. R Squared = .055 (Adjusted R Squared = -.001)

Step 5

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	748.295[a]	6	124.716	1.225	.297
Intercept	275.881	1	275.881	2.709	.102
Zone	381.597	2	190.799	1.874	.157
Strain	71.997	1	71.997	.707	.402
PopHole	5.535	1	5.535	.054	.816
Age	199.129	1	199.129	1.955	.164
FlockSize	114.740	1	114.740	1.127	.290
Error	13951.011	137	101.832		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .051 (Adjusted R Squared = .009)					

Step 6

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	633.555[a]	5	126.711	1.243	.292
Intercept	261.986	1	261.986	2.570	.111
Zone	381.597	2	190.799	1.872	.158
Strain	.078	1	.078	.001	.978
PopHole	52.751	1	52.751	.518	.473
Age	84.423	1	84.423	.828	.364
Error	14065.751	138	101.926		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .043 (Adjusted R Squared = .008)					

Step 7

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	549.132[a]	4	137.283	1.349	.255
Intercept	1320.313	1	1320.313	12.970	.000
Zone	381.597	2	190.799	1.874	.157
Strain	7.031	1	7.031	.069	.793
PopHole	50.174	1	50.174	.493	.484
Error	14150.174	139	101.800		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .037 (Adjusted R Squared = .010)					

Step 8

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of Comfort					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	498.958[a]	3	166.319	1.640	.183
Intercept	1950.694	1	1950.694	19.232	.000
Zone	381.597	2	190.799	1.881	.156
Strain	117.361	1	117.361	1.157	.284
Error	14200.347	140	101.431		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .034 (Adjusted R Squared = .013)					

Step 9

Tests of Between-Subjects Effects
Dependent Variable: Proportion of Comfort

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	381.597[a]	2	190.799	1.879	.157
Intercept	1950.694	1	1950.694	19.210	.000
Zone	381.597	2	190.799	1.879	.157
Error	14317.708	141	101.544		
Total	16650.000	144			
Corrected Total	14699.306	143			
a. R Squared = .026 (Adjusted R Squared = .012)					

Aggression

Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.885[a]	14	.135	.757	.713
Intercept	.016	1	.016	.088	.767
Zone	.031	2	.016	.088	.916
Strain	.046	1	.046	.260	.611
PopHole	.002	1	.002	.013	.910
Age	.088	1	.088	.495	.483
FlockSize	.009	1	.009	.049	.825
Zone * Strain	.093	2	.046	.260	.771
Zone * PopHole	.005	2	.002	.013	.987
Zone * Age	.176	2	.088	.495	.611
Zone * FlockSize	.018	2	.009	.049	.952
Error	22.941	129	.178		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .076 (Adjusted R Squared = -.024)					

Step 2

Tests of Between-Subjects Effects

Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.868[a]	12	.156	.888	.561
Intercept	.016	1	.016	.089	.766
Zone	.480	2	.240	1.369	.258
Strain	.046	1	.046	.264	.608
PopHole	.002	1	.002	.013	.909
Age	.088	1	.088	.502	.480
FlockSize	.009	1	.009	.050	.823
Zone * Strain	.416	2	.208	1.186	.309
Zone * PopHole	.000	2	.000	.001	.999
Zone * Age	.661	2	.330	1.885	.156
Error	22.958	131	.175		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .075 (Adjusted R Squared = -.009)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.207[a]	10	.121	.680	.742
Intercept	.016	1	.016	.088	.767
Zone	.278	2	.139	.782	.460
Strain	.046	1	.046	.261	.611
PopHole	.002	1	.002	.013	.910
Age	.088	1	.088	.496	.483
FlockSize	.009	1	.009	.049	.824
Zone * Strain	.174	2	.087	.489	.614
Zone * PopHole	.000	2	.000	.000	1.000
Error	23.619	133	.178		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .049 (Adjusted R Squared = -.023)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.207[a]	8	.151	.862	.550
Intercept	.016	1	.016	.089	.765
Zone	.347	2	.174	.992	.373
Strain	.046	1	.046	.265	.608
PopHole	.002	1	.002	.013	.909
Age	.088	1	.088	.503	.479
FlockSize	.009	1	.009	.050	.823
Zone * Strain	.347	2	.174	.992	.373
Error	23.619	135	.175		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .049 (Adjusted R Squared = -.008)					

Step 5

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.860[a]	6	.143	.819	.557
Intercept	.016	1	.016	.089	.765
Zone	.347	2	.174	.992	.373
Strain	.046	1	.046	.265	.608
PopHole	.002	1	.002	.013	.909
Age	.088	1	.088	.503	.479
FlockSize	.009	1	.009	.050	.823
Error	23.966	137	.175		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .035 (Adjusted R Squared = -.008)					

Step 6

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.851[a]	5	.170	.980	.432
Intercept	.240	1	.240	1.381	.242
Zone	.347	2	.174	.999	.371
Strain	.208	1	.208	1.197	.276
PopHole	.000	1	.000	.001	.978
Age	.330	1	.330	1.902	.170
Error	23.975	138	.174		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .034 (Adjusted R Squared = -.001)					

Step 7

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.521[a]	4	.130	.745	.563
Intercept	.139	1	.139	.794	.374
Zone	.347	2	.174	.993	.373
Strain	.087	1	.087	.496	.482
PopHole	.000	1	.000	.000	1.000
Error	24.306	139	.175		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .021 (Adjusted R Squared = -.007)					

Step 8

Tests of Between-Subjects Effects
Dependent Variable: Proportion fo Aggression

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.521[a]	3	.174	1.000	.395
Intercept	.174	1	.174	1.000	.319
Zone	.347	2	.174	1.000	.370
Strain	.174	1	.174	1.000	.319
Error	24.306	140	.174		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .021 (Adjusted R Squared = .000)					

Step 9

Tests of Between-Subjects Effects					
Dependent Variable: Proportion fo Aggression					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.347[a]	2	.174	1.000	.370
Intercept	.174	1	.174	1.000	.319
Zone	.347	2	.174	1.000	.370
Error	24.479	141	.174		
Total	25.000	144			
Corrected Total	24.826	143			
a. R Squared = .014 (Adjusted R Squared = .000)					

Distribution and behaviour models for single flock study

Model simplification processes

Models	Fixed factors	Covariates	Main effects	Interactions
Distribution	Zone Time Week	Temperature R. Humidity Wind speed	Zone Time Week Temperature R. Humidity Wind speed	Zone X Time Zone X Week Zone X Temp Zone X RH Zone X Wind
Behaviour	Behaviour Zone Week Time	Temp RH Wind speed	Behaviour Zone Week Time Temp RH Wind speed	Behaviour X Zone Behaviour X Week Behaviour X Time Behaviour X Temp Behaviour X RH Behaviour X Wind

Distribution model simplification
Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Number of hens per quadrat					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	667660.345[a]	65	10271.698	126.541	.000
Intercept	15.958	1	15.958	.197	.657
Zone	74.800	2	37.400	.461	.631
Time	1361.483	4	340.371	4.193	.002
Week	45643.954	14	3260.282	40.165	.000
RH	4.183	1	4.183	.052	.820
Temp	1724.928	1	1724.928	21.250	.000
Wind	452.580	1	452.580	5.575	.018

Zone * Week	82253.187	28	2937.614	36.189	.000
Zone * Time	4723.905	8	590.488	7.274	.000
Zone * RH	268.937	2	134.468	1.657	.191
Zone * Temp	2935.552	2	1467.776	18.082	.000
Zone * Wind	411.432	2	205.716	2.534	.079
Error	725200.679	8934	81.173		
Total	2712294.000	9000			
Corrected Total	1392861.024	8999			
a. R Squared = .479 (Adjusted R Squared = .476)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Number of hens per quadrat					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	667248.914[a]	63	10591.253	130.433	.000
Intercept	9.167	1	9.167	.113	.737
Zone	111.514	2	55.757	.687	.503
Time	1410.562	4	352.641	4.343	.002
Week	46632.505	14	3330.893	41.020	.000
RH	3.543	1	3.543	.044	.835
Temp	1916.279	1	1916.279	23.599	.000
Wind	432.854	1	432.854	5.331	.021
Zone * Week	82645.952	28	2951.641	36.350	.000
Zone * Time	4826.744	8	603.343	7.430	.000
Zone * RH	211.091	2	105.545	1.300	.273
Zone * Temp	2966.412	2	1483.206	18.266	.000
Error	725612.110	8936	81.201		
Total	2712294.000	9000			
Corrected Total	1392861.024	8999			
a. R Squared = .479 (Adjusted R Squared = .475)					

Step 3

Tests of Between-Subjects Effects
Dependent Variable: Number of hens per quadrat

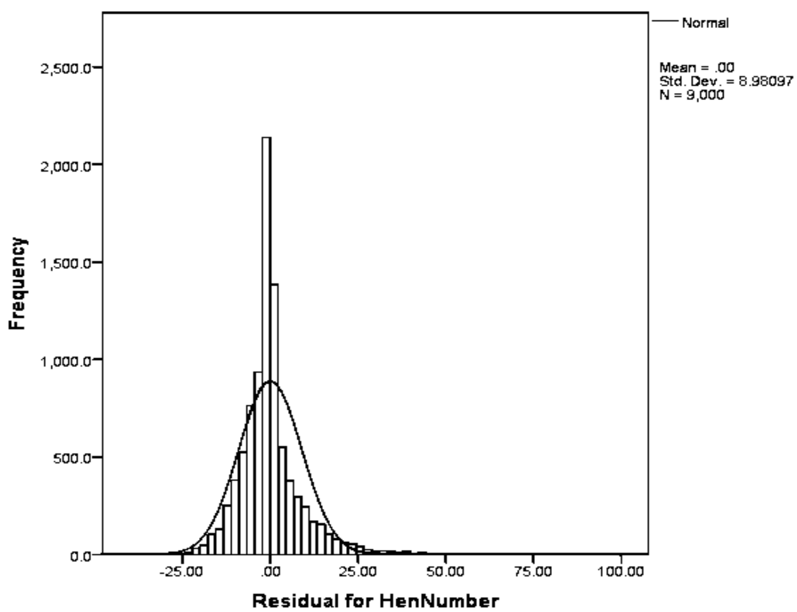
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	667037.823[a]	61	10935.046	134.657	.000
Intercept	5.316	1	5.316	.065	.798
Zone	3926.013	2	1963.007	24.173	.000
Time	1424.753	4	356.188	4.386	.002
Week	46920.646	14	3351.475	41.271	.000
RH	16.314	1	16.314	.201	.654
Temp	2848.008	1	2848.008	35.071	.000
Wind	430.575	1	430.575	5.302	.021
Zone * Week	84513.341	28	3018.334	37.169	.000
Zone * Time	4798.750	8	599.844	7.387	.000
Zone * Temp	8695.358	2	4347.679	53.539	.000
Error	725823.201	8938	81.206		
Total	2712294.000	9000			
Corrected Total	1392861.024	8999			
a. R Squared = .479 (Adjusted R Squared = .475)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Number of hens per quadrat					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	667021.509[a]	60	11117.025	136.911	.000
Intercept	9.855	1	9.855	.121	.728
Zone	3909.706	2	1954.853	24.075	.000
Time	1424.913	4	356.228	4.387	.002
Week	47136.558	14	3366.897	41.465	.000
Temp	4098.316	1	4098.316	50.472	.000
Wind	544.787	1	544.787	6.709	.010
Zone * Week	84517.002	28	3018.464	37.174	.000
Zone * Time	4783.371	8	597.921	7.364	.000
Zone * Temp	8679.301	2	4339.651	53.445	.000
Error	725839.515	8939	81.199		
Total	2712294.000	9000			
Corrected Total	1392861.024	8999			
a. R Squared = .479 (Adjusted R Squared = .475)					

Parameter Estimates						
Dependent Variable: Number of hens per quadrat						
Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	9.797	4.180	2.344	.019	1.603	17.991
RH	.014	.031	.448	.654	-.048	.076
Temp	-.421	.177	-2.371	.018	-.769	-.073
Wind	-.249	.108	-2.303	.021	-.461	-.037
[Zone=1.00] * Temp	2.654	.262	10.116	.000	2.139	3.168
[Zone=2.00] * Temp	.687	.191	3.602	.000	.313	1.062
[Zone=3.00] * Temp	0[a]	.	.	.	.	.
a. This parameter is set to zero because it is redundant.						

Normality curve for distribution



Main effects

Zone

Number of hens per quadrat * Outdoor zone
Number of hens per quadrat

Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	21.2707	3000	13.64459	.24911
Enriched	12.2897	3000	9.39133	.17146
Outer range	2.7637	3000	4.32536	.07897
Total	12.1080	9000	12.44104	.13114

Pairwise Comparisons						
Dependent Variable: Number of hens per quadrat						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Apron	Enriched	9.128*	.240	.000	8.552	9.704
	Outer range	18.668*	.254	.000	18.059	19.277
Enriched	Apron	-9.128*	.240	.000	-9.704	-8.552
	Outer range	9.540*	.252	.000	8.937	10.143
Outer range	Apron	-18.668*	.254	.000	-19.277	-18.059
	Enriched	-9.540*	.252	.000	-10.143	-8.937
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Week of access

Number of hens per quadrat * Week of outdoor access				
Number of hens per quadrat				
Week of outdoor access	Mean	N	Std. Deviation	Std. Error of Mean
Week1	5.5883	600	10.24160	.41811
Week2	8.4567	600	15.17471	.61951
Week3	11.4517	600	11.33557	.46277
Week4	12.6000	600	12.52043	.51114
Week5	12.4783	600	11.91355	.48637
Week6	11.4467	600	10.05048	.41031
Week7	12.4733	600	11.92601	.48688
Week8	13.1150	600	12.09431	.49375
Week9	11.9950	600	11.91364	.48637
Week10	14.8150	600	11.45307	.46757

Week11	12.1800	600	11.97079	.48871
Week12	12.0067	600	11.63453	.47498
Week13	11.8767	600	10.13703	.41384
Week14	16.7700	600	15.05861	.61477
Week15	14.3667	600	14.12521	.57666
Total	12.1080	9000	12.44104	.13114

Time of the day

Number of hens per quadrat * Time of the day				
Number of hens per quadrat				
Time of the day	Mean	N	Std. Deviation	Std. Error of Mean
9am	12.6367	1800	12.33041	.29063
10am	12.4122	1800	12.51996	.29510
11am	12.1956	1800	12.32552	.29052
1pm	11.8994	1800	12.69094	.29913
2pm	11.3961	1800	12.31034	.29016
Total	12.1080	9000	12.44104	.13114

Pairwise Comparisons						
Dependent Variable: Number of hens per quadrat						
(I) Time of the day	(J) Time of the day	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
9am	10am	.033	.301	1.000	-.812	.877
	11am	.255	.301	1.000	-.590	1.099
	1pm	.530	.301	.786	-.316	1.376
	2pm	1.087*	.302	.003	.239	1.935
10am	9am	-.033	.301	1.000	-.877	.812
	11am	.222	.301	1.000	-.622	1.066
	1pm	.497	.301	.985	-.348	1.342
	2pm	1.054*	.302	.005	.206	1.902
11am	9am	-.255	.301	1.000	-1.099	.590
	10am	-.222	.301	1.000	-1.066	.622
	1pm	.275	.301	1.000	-.569	1.119

	2pm	.832	.301	.057	-.014	1.678
1pm	9am	-.530	.301	.786	-1.376	.316
	10am	-.497	.301	.985	-1.342	.348
	11am	-.275	.301	1.000	-1.119	.569
	2pm	.557	.301	.640	-.287	1.402
2pm	9am	-1.087*	.302	.003	-1.935	-.239
	10am	-1.054*	.302	.005	-1.902	-.206
	11am	-.832	.301	.057	-1.678	.014
	1pm	-.557	.301	.640	-1.402	.287
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Interactions

Zone X Week

Descriptives									
Number of hens per quadrat									
Outdoor zone		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Apron	Week1	200	16.7650	11.28746	.79814	15.1911	18.3389	.00	65.00
	Week2	200	25.3700	16.18278	1.14430	23.1135	27.6265	.00	91.00
	Week3	200	21.2700	10.75198	.76028	19.7708	22.7692	6.00	67.00
	Week4	200	23.5700	11.14117	.78780	22.0165	25.1235	6.00	69.00
	Week5	200	22.6850	11.85659	.83839	21.0317	24.3383	5.00	124.00
	Week6	200	17.6200	8.14600	.57601	16.4841	18.7559	3.00	45.00
	Week7	200	21.4550	11.80231	.83455	19.8093	23.1007	3.00	60.00
	Week8	200	21.4500	11.13767	.78755	19.8970	23.0030	.00	61.00
	Week9	200	19.6350	15.80986	1.11793	17.4305	21.8395	.00	70.00
	Week10	200	24.8550	11.72310	.82895	23.2203	26.4897	3.00	64.00
	Week11	200	18.7950	11.36657	.80374	17.2101	20.3799	1.00	75.00
	Week12	200	16.2950	13.21176	.93421	14.4528	18.1372	.00	63.00
	Week13	200	16.8800	13.31246	.94133	15.0237	18.7363	.00	60.00
	Week14	200	29.6100	17.52551	1.23924	27.1663	32.0537	.00	96.00
	Week15	200	22.8050	18.29125	1.29339	20.2545	25.3555	.00	108.00
	Total	3000	21.2707	13.64459	.24911	20.7822	21.7591	.00	124.00

Enriched	Week1	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Week2	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Week3	200	13.0850	6.30926	.44613	12.2052	13.9648	3.00	34.00
	Week4	200	13.7900	8.59975	.60809	12.5909	14.9891	3.00	69.00
	Week5	200	13.5650	6.69476	.47339	12.6315	14.4985	3.00	40.00
	Week6	200	15.7250	7.67685	.54284	14.6546	16.7954	3.00	42.00
	Week7	200	15.5600	7.05160	.49862	14.5767	16.5433	4.00	39.00
	Week8	200	15.9900	9.68861	.68509	14.6390	17.3410	3.00	53.00
	Week9	200	11.0050	7.72615	.54632	9.9277	12.0823	.00	36.00
	Week10	200	13.9750	7.32274	.51780	12.9539	14.9961	.00	41.00
	Week11	200	16.2900	10.76687	.76133	14.7887	17.7913	2.00	59.00
	Week12	200	15.1700	11.23710	.79458	13.6031	16.7369	1.00	75.00
	Week13	200	12.1200	7.13513	.50453	11.1251	13.1149	2.00	42.00
	Week14	200	13.0300	9.03422	.63882	11.7703	14.2897	3.00	53.00
	Week15	200	15.0400	9.91970	.70143	13.6568	16.4232	3.00	52.00
	Total	3000	12.2897	9.39133	.17146	11.9535	12.6259	.00	75.00
Outer range	Week1	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Week2	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Week3	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Week4	200	.4400	1.67344	.11833	.2067	.6733	.00	11.00
	Week5	200	1.1850	2.78560	.19697	.7966	1.5734	.00	13.00
	Week6	200	.9950	3.50376	.24775	.5064	1.4836	.00	35.00
	Week7	200	.4050	1.43921	.10177	.2043	.6057	.00	12.00
	Week8	200	1.9050	4.23624	.29955	1.3143	2.4957	.00	22.00
	Week9	200	5.3450	3.67334	.25974	4.8328	5.8572	.00	21.00
	Week10	200	5.6150	4.08660	.28897	5.0452	6.1848	1.00	33.00
	Week11	200	1.4550	3.10745	.21973	1.0217	1.8883	.00	21.00
	Week12	200	4.5550	4.72000	.33375	3.8969	5.2131	.00	29.00
	Week13	200	6.6300	5.31926	.37613	5.8883	7.3717	.00	33.00
	Week14	200	7.6700	5.55205	.39259	6.8958	8.4442	1.00	37.00
	Week15	200	5.2550	3.48435	.24638	4.7691	5.7409	1.00	23.00
	Total	3000	2.7637	4.32536	.07897	2.6088	2.9185	.00	37.00

ANOVA
Number of hens per quadrat

Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	39074.399	14	2791.028	16.044	.000
	Within Groups	519263.820	2985	173.958		
	Total	558338.219	2999			
Enriched	Between Groups	75940.365	14	5424.312	85.868	.000
	Within Groups	188562.915	2985	63.170		
	Total	264503.280	2999			
Outer range	Between Groups	21035.245	14	1502.517	127.879	.000
	Within Groups	35072.195	2985	11.749		
	Total	56107.440	2999			

Week X Zone

Descriptives

Number of hens per quadrat

Week of outdoor access		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Week1	Apron	200	16.7650	11.28746	.79814	15.1911	18.3389	.00	65.00
	Enriched	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Outer range	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	600	5.5883	10.24160	.41811	4.7672	6.4095	.00	65.00
Week2	Apron	200	25.3700	16.18278	1.14430	23.1135	27.6265	.00	91.00
	Enriched	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Outer range	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	600	8.4567	15.17471	.61951	7.2400	9.6733	.00	91.00
Week3	Apron	200	21.2700	10.75198	.76028	19.7708	22.7692	6.00	67.00
	Enriched	200	13.0850	6.30926	.44613	12.2052	13.9648	3.00	34.00
	Outer range	200	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	600	11.4517	11.33557	.46277	10.5428	12.3605	.00	67.00
Week4	Apron	200	23.5700	11.14117	.78780	22.0165	25.1235	6.00	69.00
	Enriched	200	13.7900	8.59975	.60809	12.5909	14.9891	3.00	69.00

	Outer range	200	.4400	1.67344	.11833	.2067	.6733	.00	11.00
	Total	600	12.6000	12.52043	.51114	11.5961	13.6039	.00	69.00
Week5	Apron	200	22.6850	11.85659	.83839	21.0317	24.3383	5.00	124.00
	Enriched	200	13.5650	6.69476	.47339	12.6315	14.4985	3.00	40.00
	Outer range	200	1.1850	2.78560	.19697	.7966	1.5734	.00	13.00
	Total	600	12.4783	11.91355	.48637	11.5231	13.4335	.00	124.00
Week6	Apron	200	17.6200	8.14600	.57601	16.4841	18.7559	3.00	45.00
	Enriched	200	15.7250	7.67685	.54284	14.6546	16.7954	3.00	42.00
	Outer range	200	.9950	3.50376	.24775	.5064	1.4836	.00	35.00
	Total	600	11.4467	10.05048	.41031	10.6408	12.2525	.00	45.00
Week7	Apron	200	21.4550	11.80231	.83455	19.8093	23.1007	3.00	60.00
	Enriched	200	15.5600	7.05160	.49862	14.5767	16.5433	4.00	39.00
	Outer range	200	.4050	1.43921	.10177	.2043	.6057	.00	12.00
	Total	600	12.4733	11.92601	.48688	11.5171	13.4295	.00	60.00
Week8	Apron	200	21.4500	11.13767	.78755	19.8970	23.0030	.00	61.00
	Enriched	200	15.9900	9.68861	.68509	14.6390	17.3410	3.00	53.00
	Outer range	200	1.9050	4.23624	.29955	1.3143	2.4957	.00	22.00
	Total	600	13.1150	12.09431	.49375	12.1453	14.0847	.00	61.00
Week9	Apron	200	19.6350	15.80986	1.11793	17.4305	21.8395	.00	70.00
	Enriched	200	11.0050	7.72615	.54632	9.9277	12.0823	.00	36.00
	Outer range	200	5.3450	3.67334	.25974	4.8328	5.8572	.00	21.00
	Total	600	11.9950	11.91364	.48637	11.0398	12.9502	.00	70.00
Week10	Apron	200	24.8550	11.72310	.82895	23.2203	26.4897	3.00	64.00
	Enriched	200	13.9750	7.32274	.51780	12.9539	14.9961	.00	41.00
	Outer range	200	5.6150	4.08660	.28897	5.0452	6.1848	1.00	33.00
	Total	600	14.8150	11.45307	.46757	13.8967	15.7333	.00	64.00
Week11	Apron	200	18.7950	11.36657	.80374	17.2101	20.3799	1.00	75.00
	Enriched	200	16.2900	10.76687	.76133	14.7887	17.7913	2.00	59.00
	Outer range	200	1.4550	3.10745	.21973	1.0217	1.8883	.00	21.00
	Total	600	12.1800	11.97079	.48871	11.2202	13.1398	.00	75.00
Week12	Apron	200	16.2950	13.21176	.93421	14.4528	18.1372	.00	63.00

	Enriched	200	15.1700	11.23710	.79458	13.6031	16.7369	1.00	75.00
	Outer range	200	4.5550	4.72000	.33375	3.8969	5.2131	.00	29.00
	Total	600	12.0067	11.63453	.47498	11.0738	12.9395	.00	75.00
Week13	Apron	200	16.8800	13.31246	.94133	15.0237	18.7363	.00	60.00
	Enriched	200	12.1200	7.13513	.50453	11.1251	13.1149	2.00	42.00
	Outer range	200	6.6300	5.31926	.37613	5.8883	7.3717	.00	33.00
	Total	600	11.8767	10.13703	.41384	11.0639	12.6894	.00	60.00
Week14	Apron	200	29.6100	17.52551	1.23924	27.1663	32.0537	.00	96.00
	Enriched	200	13.0300	9.03422	.63882	11.7703	14.2897	3.00	53.00
	Outer range	200	7.6700	5.55205	.39259	6.8958	8.4442	1.00	37.00
	Total	600	16.7700	15.05861	.61477	15.5626	17.9774	.00	96.00
Week15	Apron	200	22.8050	18.29125	1.29339	20.2545	25.3555	.00	108.00
	Enriched	200	15.0400	9.91970	.70143	13.6568	16.4232	3.00	52.00
	Outer range	200	5.2550	3.48435	.24638	4.7691	5.7409	1.00	23.00
	Total	600	14.3667	14.12521	.57666	13.2341	15.4992	.00	108.00

ANOVA

Number of hens per quadrat

Week of outdoor access		Sum of Squares	df	Mean Square	F	Sig.
Week1	Between Groups	37475.363	2	18737.682	441.209	.000
	Within Groups	25353.955	597	42.469		
	Total	62829.318	599			
Week2	Between Groups	85818.253	2	42909.127	491.546	.000
	Within Groups	52114.620	597	87.294		
	Total	137932.873	599			
Week3	Between Groups	46041.623	2	23020.812	444.383	.000
	Within Groups	30926.975	597	51.804		
	Total	76968.598	599			
Week4	Between Groups	53924.520	2	26962.260	402.659	.000
	Within Groups	39975.480	597	66.961		
	Total	93900.000	599			
Week5	Between Groups	46579.253	2	23289.627	361.719	.000

	Within Groups	38438.465	597	64.386		
	Total	85017.718	599			
Week6	Between Groups	33130.303	2	16565.152	361.243	.000
	Within Groups	27375.990	597	45.856		
	Total	60506.293	599			
Week7	Between Groups	47168.503	2	23584.252	370.257	.000
	Within Groups	38027.070	597	63.697		
	Total	85195.573	599			
Week8	Between Groups	40680.390	2	20340.195	258.712	.000
	Within Groups	46936.675	597	78.621		
	Total	87617.065	599			
Week9	Between Groups	20714.440	2	10357.220	96.156	.000
	Within Groups	64304.545	597	107.713		
	Total	85018.985	599			
Week10	Between Groups	37229.440	2	18614.720	268.800	.000
	Within Groups	41343.025	597	69.251		
	Total	78572.465	599			
Week11	Between Groups	35135.190	2	17567.595	206.855	.000
	Within Groups	50701.370	597	84.927		
	Total	85836.560	599			
Week12	Between Groups	16784.763	2	8392.382	77.923	.000
	Within Groups	64297.210	597	107.701		
	Total	81081.973	599			
Week13	Between Groups	10524.013	2	5262.007	61.562	.000
	Within Groups	51028.860	597	85.475		
	Total	61552.873	599			
Week14	Between Groups	52332.640	2	26166.320	187.087	.000
	Within Groups	83497.620	597	139.862		
	Total	135830.260	599			
Week15	Between Groups	30936.263	2	15468.132	104.254	.000
	Within Groups	88577.070	597	148.370		
	Total	119513.333	599			

Multiple Comparisons
Dependent Variable: Number of hens per quadrat
Bonferroni

Week of outdoor access	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Week1	Apron	Enriched	16.76500*	.65168	.000	15.2005	18.3295
		Outer range	16.76500*	.65168	.000	15.2005	18.3295
	Enriched	Apron	-16.76500*	.65168	.000	-18.3295	-15.2005
		Outer range	.00000	.65168	1.000	-1.5645	1.5645
	Outer range	Apron	-16.76500*	.65168	.000	-18.3295	-15.2005
		Enriched	.00000	.65168	1.000	-1.5645	1.5645
Week2	Apron	Enriched	25.37000*	.93431	.000	23.1270	27.6130
		Outer range	25.37000*	.93431	.000	23.1270	27.6130
	Enriched	Apron	-25.37000*	.93431	.000	-27.6130	-23.1270
		Outer range	.00000	.93431	1.000	-2.2430	2.2430
	Outer range	Apron	-25.37000*	.93431	.000	-27.6130	-23.1270
		Enriched	.00000	.93431	1.000	-2.2430	2.2430
Week3	Apron	Enriched	8.18500*	.71975	.000	6.4571	9.9129
		Outer range	21.27000*	.71975	.000	19.5421	22.9979
	Enriched	Apron	-8.18500*	.71975	.000	-9.9129	-6.4571
		Outer range	13.08500*	.71975	.000	11.3571	14.8129
	Outer range	Apron	-21.27000*	.71975	.000	-22.9979	-19.5421
		Enriched	-13.08500*	.71975	.000	-14.8129	-11.3571
Week4	Apron	Enriched	9.78000*	.81829	.000	7.8155	11.7445
		Outer range	23.13000*	.81829	.000	21.1655	25.0945
	Enriched	Apron	-9.78000*	.81829	.000	-11.7445	-7.8155
		Outer range	13.35000*	.81829	.000	11.3855	15.3145
	Outer range	Apron	-23.13000*	.81829	.000	-25.0945	-21.1655
		Enriched	-13.35000*	.81829	.000	-15.3145	-11.3855
Week5	Apron	Enriched	9.12000*	.80241	.000	7.1936	11.0464
		Outer range	21.50000*	.80241	.000	19.5736	23.4264
	Enriched	Apron	-9.12000*	.80241	.000	-11.0464	-7.1936
		Outer range	12.38000*	.80241	.000	10.4536	14.3064
	Outer range	Apron	-21.50000*	.80241	.000	-23.4264	-19.5736
		Enriched	-12.38000*	.80241	.000	-14.3064	-10.4536
Week6	Apron	Enriched	1.89500*	.67717	.016	.2693	3.5207
		Outer range	16.62500*	.67717	.000	14.9993	18.2507
	Enriched	Apron	-1.89500*	.67717	.016	-3.5207	-.2693
		Outer range	14.73000*	.67717	.000	13.1043	16.3557
	Outer range	Apron	-16.62500*	.67717	.000	-18.2507	-14.9993

		Enriched	-14.73000*	.67717	.000	-16.3557	-13.1043
Week7	Apron	Enriched	5.89500*	.79810	.000	3.9790	7.8110
		Outer range	21.05000*	.79810	.000	19.1340	22.9660
	Enriched	Apron	-5.89500*	.79810	.000	-7.8110	-3.9790
		Outer range	15.15500*	.79810	.000	13.2390	17.0710
	Outer range	Apron	-21.05000*	.79810	.000	-22.9660	-19.1340
		Enriched	-15.15500*	.79810	.000	-17.0710	-13.2390
Week8	Apron	Enriched	5.46000*	.88668	.000	3.3313	7.5887
		Outer range	19.54500*	.88668	.000	17.4163	21.6737
	Enriched	Apron	-5.46000*	.88668	.000	-7.5887	-3.3313
		Outer range	14.08500*	.88668	.000	11.9563	16.2137
	Outer range	Apron	-19.54500*	.88668	.000	-21.6737	-17.4163
		Enriched	-14.08500*	.88668	.000	-16.2137	-11.9563
Week9	Apron	Enriched	8.63000*	1.03785	.000	6.1384	11.1216
		Outer range	14.29000*	1.03785	.000	11.7984	16.7816
	Enriched	Apron	-8.63000*	1.03785	.000	-11.1216	-6.1384
		Outer range	5.66000*	1.03785	.000	3.1684	8.1516
	Outer range	Apron	-14.29000*	1.03785	.000	-16.7816	-11.7984
		Enriched	-5.66000*	1.03785	.000	-8.1516	-3.1684
Week10	Apron	Enriched	10.88000*	.83217	.000	8.8822	12.8778
		Outer range	19.24000*	.83217	.000	17.2422	21.2378
	Enriched	Apron	-10.88000*	.83217	.000	-12.8778	-8.8822
		Outer range	8.36000*	.83217	.000	6.3622	10.3578
	Outer range	Apron	-19.24000*	.83217	.000	-21.2378	-17.2422
		Enriched	-8.36000*	.83217	.000	-10.3578	-6.3622
Week11	Apron	Enriched	2.50500*	.92156	.020	.2926	4.7174
		Outer range	17.34000*	.92156	.000	15.1276	19.5524
	Enriched	Apron	-2.50500*	.92156	.020	-4.7174	-.2926
		Outer range	14.83500*	.92156	.000	12.6226	17.0474
	Outer range	Apron	-17.34000*	.92156	.000	-19.5524	-15.1276
		Enriched	-14.83500*	.92156	.000	-17.0474	-12.6226
Week12	Apron	Enriched	1.12500	1.03779	.836	-1.3665	3.6165
		Outer range	11.74000*	1.03779	.000	9.2485	14.2315
	Enriched	Apron	-1.12500	1.03779	.836	-3.6165	1.3665
		Outer range	10.61500*	1.03779	.000	8.1235	13.1065
	Outer range	Apron	-11.74000*	1.03779	.000	-14.2315	-9.2485
		Enriched	-10.61500*	1.03779	.000	-13.1065	-8.1235
Week13	Apron	Enriched	4.76000*	.92453	.000	2.5404	6.9796
		Outer range	10.25000*	.92453	.000	8.0304	12.4696

	Enriched	Apron	-4.76000*	.92453	.000	-6.9796	-2.5404
		Outer range	5.49000*	.92453	.000	3.2704	7.7096
	Outer range	Apron	-10.25000*	.92453	.000	-12.4696	-8.0304
		Enriched	-5.49000*	.92453	.000	-7.7096	-3.2704
Week14	Apron	Enriched	16.58000*	1.18263	.000	13.7408	19.4192
		Outer range	21.94000*	1.18263	.000	19.1008	24.7792
	Enriched	Apron	-16.58000*	1.18263	.000	-19.4192	-13.7408
		Outer range	5.36000*	1.18263	.000	2.5208	8.1992
	Outer range	Apron	-21.94000*	1.18263	.000	-24.7792	-19.1008
		Enriched	-5.36000*	1.18263	.000	-8.1992	-2.5208
Week15	Apron	Enriched	7.76500*	1.21807	.000	4.8407	10.6893
		Outer range	17.55000*	1.21807	.000	14.6257	20.4743
	Enriched	Apron	-7.76500*	1.21807	.000	-10.6893	-4.8407
		Outer range	9.78500*	1.21807	.000	6.8607	12.7093
	Outer range	Apron	-17.55000*	1.21807	.000	-20.4743	-14.6257
		Enriched	-9.78500*	1.21807	.000	-12.7093	-6.8607
*. The mean difference is significant at the 0.05 level.							

Zone X Time

Descriptives									
Number of hens per quadrat									
Outdoor zone		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Apron	9am	600	22.2317	13.54094	.55281	21.1460	23.3173	2.00	96.00
	10am	600	22.6450	13.61830	.55596	21.5531	23.7369	1.00	124.00
	11am	600	21.3833	12.80506	.52276	20.3567	22.4100	.00	95.00
	1pm	600	20.7817	14.11155	.57610	19.6502	21.9131	.00	89.00
	2pm	600	19.3117	13.90264	.56757	18.1970	20.4263	.00	75.00
	Total	3000	21.2707	13.64459	.24911	20.7822	21.7591	.00	124.00
Enriched	9am	600	12.1117	8.79326	.35898	11.4066	12.8167	.00	53.00
	10am	600	11.3767	8.47434	.34596	10.6972	12.0561	.00	59.00
	11am	600	12.6250	9.87118	.40299	11.8336	13.4164	.00	75.00
	1pm	600	12.6183	9.96284	.40673	11.8195	13.4171	.00	69.00
	2pm	600	12.7167	9.71959	.39680	11.9374	13.4960	.00	55.00
	Total	3000	12.2897	9.39133	.17146	11.9535	12.6259	.00	75.00
	9am	600	3.5667	4.58810	.18731	3.1988	3.9345	.00	36.00

Outer range	10am	600	3.2150	4.77599	.19498	2.8321	3.5979	.00	33.00
	11am	600	2.5783	4.17927	.17062	2.2433	2.9134	.00	31.00
	1pm	600	2.2983	3.66675	.14969	2.0043	2.5923	.00	22.00
	2pm	600	2.1600	4.17494	.17044	1.8253	2.4947	.00	37.00
	Total	3000	2.7637	4.32536	.07897	2.6088	2.9185	.00	37.00

ANOVA

Number of hens per quadrat

Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	4141.085	4	1035.271	5.595	.000
	Within Groups	554197.133	2995	185.041		
	Total	558338.219	2999			
Enriched	Between Groups	760.831	4	190.208	2.160	.071
	Within Groups	263742.448	2995	88.061		
	Total	264503.280	2999			
Outer range	Between Groups	878.285	4	219.571	11.907	.000
	Within Groups	55229.155	2995	18.440		
	Total	56107.440	2999			

Multiple Comparisons

Dependent Variable: Number of hens per quadrat

Bonferroni

Outdoor zone	(I) Time of the day	(J) Time of the day	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Apron	9am	10am	-.41333	.78537	1.000	-2.6195	1.7929
		11am	.84833	.78537	1.000	-1.3579	3.0545
		1pm	1.45000	.78537	.650	-.7562	3.6562
		2pm	2.92000*	.78537	.002	.7138	5.1262
	10am	9am	.41333	.78537	1.000	-1.7929	2.6195
		11am	1.26167	.78537	1.000	-.9445	3.4679
		1pm	1.86333	.78537	.177	-.3429	4.0695
		2pm	3.33333*	.78537	.000	1.1271	5.5395
	11am	9am	-.84833	.78537	1.000	-3.0545	1.3579
		10am	-1.26167	.78537	1.000	-3.4679	.9445

		1pm	.60167	.78537	1.000	-1.6045	2.8079
		2pm	2.07167	.78537	.084	-.1345	4.2779
	1pm	9am	-1.45000	.78537	.650	-3.6562	.7562
		10am	-1.86333	.78537	.177	-4.0695	.3429
		11am	-.60167	.78537	1.000	-2.8079	1.6045
		2pm	1.47000	.78537	.613	-.7362	3.6762
	2pm	9am	-2.92000*	.78537	.002	-5.1262	-.7138
		10am	-3.33333*	.78537	.000	-5.5395	-1.1271
		11am	-2.07167	.78537	.084	-4.2779	.1345
		1pm	-1.47000	.78537	.613	-3.6762	.7362
Enriched	9am	10am	.73500	.54179	1.000	-.7870	2.2570
		11am	-.51333	.54179	1.000	-2.0353	1.0086
		1pm	-.50667	.54179	1.000	-2.0286	1.0153
		2pm	-.60500	.54179	1.000	-2.1270	.9170
	10am	9am	-.73500	.54179	1.000	-2.2570	.7870
		11am	-1.24833	.54179	.213	-2.7703	.2736
		1pm	-1.24167	.54179	.220	-2.7636	.2803
		2pm	-1.34000	.54179	.134	-2.8620	.1820
	11am	9am	.51333	.54179	1.000	-1.0086	2.0353
		10am	1.24833	.54179	.213	-.2736	2.7703
		1pm	.00667	.54179	1.000	-1.5153	1.5286
		2pm	-.09167	.54179	1.000	-1.6136	1.4303
	1pm	9am	.50667	.54179	1.000	-1.0153	2.0286
		10am	1.24167	.54179	.220	-.2803	2.7636
		11am	-.00667	.54179	1.000	-1.5286	1.5153
		2pm	-.09833	.54179	1.000	-1.6203	1.4236
	2pm	9am	.60500	.54179	1.000	-.9170	2.1270
		10am	1.34000	.54179	.134	-.1820	2.8620
		11am	.09167	.54179	1.000	-1.4303	1.6136
		1pm	.09833	.54179	1.000	-1.4236	1.6203
Outer range	9am	10am	.35167	.24793	1.000	-.3448	1.0481
		11am	.98833*	.24793	.001	.2919	1.6848
		1pm	1.26833*	.24793	.000	.5719	1.9648
		2pm	1.40667*	.24793	.000	.7102	2.1031
	10am	9am	-.35167	.24793	1.000	-1.0481	.3448
		11am	.63667	.24793	.103	-.0598	1.3331
		1pm	.91667*	.24793	.002	.2202	1.6131
		2pm	1.05500*	.24793	.000	.3585	1.7515
	11am	9am	-.98833*	.24793	.001	-1.6848	-.2919

		10am	-.63667	.24793	.103	-1.3331	.0598
		1pm	.28000	.24793	1.000	-.4165	.9765
		2pm	.41833	.24793	.916	-.2781	1.1148
	1pm	9am	-1.26833*	.24793	.000	-1.9648	-.5719
		10am	-.91667*	.24793	.002	-1.6131	-.2202
		11am	-.28000	.24793	1.000	-.9765	.4165
		2pm	.13833	.24793	1.000	-.5581	.8348
	2pm	9am	-1.40667*	.24793	.000	-2.1031	-.7102
		10am	-1.05500*	.24793	.000	-1.7515	-.3585
		11am	-.41833	.24793	.916	-1.1148	.2781
		1pm	-.13833	.24793	1.000	-.8348	.5581
*. The mean difference is significant at the 0.05 level.							

Time X Week

Descriptives									
Number of hens per quadrat									
Time of the day		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
9am	Apron	600	22.2317	13.54094	.55281	21.1460	23.3173	2.00	96.00
	Enriched	600	12.1117	8.79326	.35898	11.4066	12.8167	.00	53.00
	Outer range	600	3.5667	4.58810	.18731	3.1988	3.9345	.00	36.00
	Total	1800	12.6367	12.33041	.29063	12.0667	13.2067	.00	96.00
10am	Apron	600	22.6450	13.61830	.55596	21.5531	23.7369	1.00	124.00
	Enriched	600	11.3767	8.47434	.34596	10.6972	12.0561	.00	59.00
	Outer range	600	3.2150	4.77599	.19498	2.8321	3.5979	.00	33.00
	Total	1800	12.4122	12.51996	.29510	11.8335	12.9910	.00	124.00
11am	Apron	600	21.3833	12.80506	.52276	20.3567	22.4100	.00	95.00
	Enriched	600	12.6250	9.87118	.40299	11.8336	13.4164	.00	75.00
	Outer range	600	2.5783	4.17927	.17062	2.2433	2.9134	.00	31.00
	Total	1800	12.1956	12.32552	.29052	11.6258	12.7653	.00	95.00
1pm	Apron	600	20.7817	14.11155	.57610	19.6502	21.9131	.00	89.00
	Enriched	600	12.6183	9.96284	.40673	11.8195	13.4171	.00	69.00

	Outer range	600	2.2983	3.66675	.14969	2.0043	2.5923	.00	22.00
	Total	1800	11.8994	12.69094	.29913	11.3128	12.4861	.00	89.00
2pm	Apron	600	19.3117	13.90264	.56757	18.1970	20.4263	.00	75.00
	Enriched	600	12.7167	9.71959	.39680	11.9374	13.4960	.00	55.00
	Outer range	600	2.1600	4.17494	.17044	1.8253	2.4947	.00	37.00
	Total	1800	11.3961	12.31034	.29016	10.8270	11.9652	.00	75.00

ANOVA						
Number of hens per quadrat						
Time of the day		Sum of Squares	df	Mean Square	F	Sig.
9am	Between Groups	104762.730	2	52381.365	557.785	.000
	Within Groups	168755.650	1797	93.910		
	Total	273518.380	1799			
10am	Between Groups	114222.608	2	57111.304	611.726	.000
	Within Groups	167769.523	1797	93.361		
	Total	281992.131	1799			
11am	Between Groups	106254.388	2	53127.194	571.514	.000
	Within Groups	167046.777	1797	92.959		
	Total	273301.164	1799			
1pm	Between Groups	102955.204	2	51477.602	495.232	.000
	Within Groups	186791.595	1797	103.946		
	Total	289746.799	1799			
2pm	Between Groups	89823.381	2	44911.691	441.488	.000
	Within Groups	182805.192	1797	101.728		
	Total	272628.573	1799			

Multiple Comparisons						
Dependent Variable: Number of hens per quadrat						
Bonferroni						
					Sig.	95% Confidence Interval

Time of the day	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error		Lower Bound	Upper Bound
9am	Apron	Enriched	10.12000*	.55949	.000	8.7793	11.4607
		Outer range	18.66500*	.55949	.000	17.3243	20.0057
	Enriched	Apron	-10.12000*	.55949	.000	-11.4607	-8.7793
		Outer range	8.54500*	.55949	.000	7.2043	9.8857
	Outer range	Apron	-18.66500*	.55949	.000	-20.0057	-17.3243
		Enriched	-8.54500*	.55949	.000	-9.8857	-7.2043
10am	Apron	Enriched	11.26833*	.55786	.000	9.9316	12.6051
		Outer range	19.43000*	.55786	.000	18.0933	20.7667
	Enriched	Apron	-11.26833*	.55786	.000	-12.6051	-9.9316
		Outer range	8.16167*	.55786	.000	6.8249	9.4984
	Outer range	Apron	-19.43000*	.55786	.000	-20.7667	-18.0933
		Enriched	-8.16167*	.55786	.000	-9.4984	-6.8249
11am	Apron	Enriched	8.75833*	.55665	.000	7.4245	10.0922
		Outer range	18.80500*	.55665	.000	17.4711	20.1389
	Enriched	Apron	-8.75833*	.55665	.000	-10.0922	-7.4245
		Outer range	10.04667*	.55665	.000	8.7128	11.3805
	Outer range	Apron	-18.80500*	.55665	.000	-20.1389	-17.4711
		Enriched	-10.04667*	.55665	.000	-11.3805	-8.7128
1pm	Apron	Enriched	8.16333*	.58863	.000	6.7528	9.5738
		Outer range	18.48333*	.58863	.000	17.0728	19.8938
	Enriched	Apron	-8.16333*	.58863	.000	-9.5738	-6.7528
		Outer range	10.32000*	.58863	.000	8.9095	11.7305
	Outer range	Apron	-18.48333*	.58863	.000	-19.8938	-17.0728
		Enriched	-10.32000*	.58863	.000	-11.7305	-8.9095
2pm	Apron	Enriched	6.59500*	.58232	.000	5.1996	7.9904
		Outer range	17.15167*	.58232	.000	15.7563	18.5470
	Enriched	Apron	-6.59500*	.58232	.000	-7.9904	-5.1996
		Outer range	10.55667*	.58232	.000	9.1613	11.9520
	Outer range	Apron	-17.15167*	.58232	.000	-18.5470	-15.7563
		Enriched	-10.55667*	.58232	.000	-11.9520	-9.1613
*. The mean difference is significant at the 0.05 level.							

Weather descriptive

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation

	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Relative humidity	9000	44.00	90.00	70.7122	.11448	10.86075
Temperature	9000	9.10	28.80	18.5991	.04836	4.58802
Wind speed	9000	.00	9.50	3.2702	.01739	1.64947
Valid N (listwise)	9000					

Behaviour model simplification process

Principal component analysis output

Warnings
There are fewer than two cases, at least one of the variables has zero variance, there is only one variable in the analysis, or correlation coefficients could not be computed for all pairs of variables. No further statistics will be computed.

Descriptives

Descriptive Statistics			
	N	Mean	
	Statistic	Statistic	Std. Error
Proportion of resting behaviour	6797	28.9962	.32485
Proportion of appetitive+Foraging behaviour	6797	32.8526	.32312
Proportion of locomotive behaviour	6797	36.3229	.31676
Proportion of comfort behaviour	6797	1.8280	.08284
Proportion of aggressive behaviour	6797	.0000	.00000
Valid N (listwise)	6797		

Resting behaviour

Step1

Tests of Between-Subjects Effects

Dependent Variable: Proportion of resting behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	904403.774[a]	55	16443.705	27.921	.000
Intercept	7051.162	1	7051.162	11.973	.001
Zone	265253.211	2	132626.605	225.197	.000
Week	91849.172	14	6560.655	11.140	.000
Time	2741.350	4	685.337	1.164	.325
RH	672.838	1	672.838	1.142	.285
Temp	274.775	1	274.775	.467	.495
Wind	2146.028	1	2146.028	3.644	.056
Zone * Week	51864.119	24	2161.005	3.669	.000
Zone * Time	7131.847	8	891.481	1.514	.147
Error	3970020.588	6741	588.936		
Total	10589205.060	6797			
Corrected Total	4874424.362	6796			
a. R Squared = .186 (Adjusted R Squared = .179)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	897271.927[a]	47	19090.892	32.396	.000
Intercept	7304.863	1	7304.863	12.396	.000
Zone	297885.638	2	148942.819	252.747	.000
Week	93331.436	14	6666.531	11.313	.000
Time	3279.144	4	819.786	1.391	.234
RH	727.980	1	727.980	1.235	.266
Temp	347.330	1	347.330	.589	.443
Wind	2086.640	1	2086.640	3.541	.060
Zone * Week	51953.504	24	2164.729	3.673	.000
Error	3977152.435	6749	589.295		
Total	10589205.060	6797			
Corrected Total	4874424.362	6796			
a. R Squared = .184 (Adjusted R Squared = .178)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	895185.287[a]	46	19460.550	33.011	.000
Intercept	5350.287	1	5350.287	9.076	.003
Zone	330572.510	2	165286.255	280.376	.000
Week	96717.453	14	6908.390	11.719	.000
Time	3527.496	4	881.874	1.496	.201
RH	114.741	1	114.741	.195	.659
Temp	94.613	1	94.613	.160	.689
Zone * Week	52497.562	24	2187.398	3.710	.000
Error	3979239.075	6750	589.517		
Total	10589205.060	6797			
Corrected Total	4874424.362	6796			
a. R Squared = .184 (Adjusted R Squared = .178)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	895090.674[a]	45	19890.904	33.745	.000
Intercept	18502.923	1	18502.923	31.390	.000
Zone	330507.268	2	165253.634	280.355	.000
Week	98012.015	14	7000.858	11.877	.000
Time	3506.893	4	876.723	1.487	.203
RH	37.236	1	37.236	.063	.802
Zone * Week	53153.500	24	2214.729	3.757	.000
Error	3979333.688	6751	589.444		
Total	10589205.060	6797			
Corrected Total	4874424.362	6796			
a. R Squared = .184 (Adjusted R Squared = .178)					

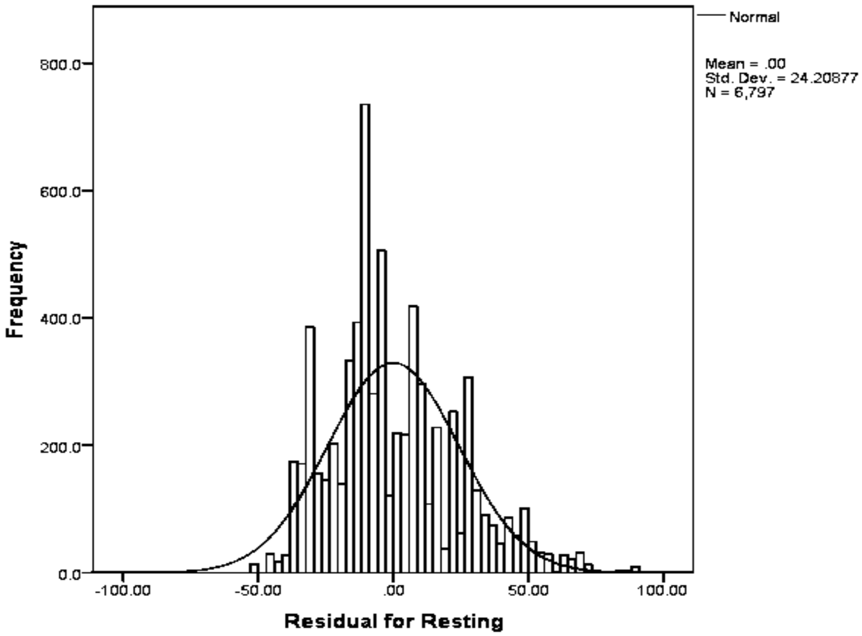
Step 5

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	895053.438[a]	44	20342.124	34.516	.000
Intercept	1811790.735	1	1811790.735	3074.157	.000
Zone	349448.327	2	174724.164	296.463	.000
Week	98117.173	14	7008.369	11.891	.000
Time	3524.442	4	881.111	1.495	.201
Zone * Week	54674.249	24	2278.094	3.865	.000
Error	3979370.924	6752	589.362		
Total	10589205.060	6797			
Corrected Total	4874424.362	6796			
a. R Squared = .184 (Adjusted R Squared = .178)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of resting behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	891528.995[a]	40	22288.225	37.806	.000
Intercept	1889992.523	1	1889992.523	3205.906	.000
Zone	347736.334	2	173868.167	294.924	.000
Week	96823.309	14	6915.951	11.731	.000
Zone * Week	54442.095	24	2268.421	3.848	.000
Error	3982895.367	6756	589.535		
Total	10589205.060	6797			
Corrected Total	4874424.362	6796			
a. R Squared = .183 (Adjusted R Squared = .178)					

Normal distribution curve for resting residual



Main effects

Zone

Proportion of resting behaviour * Outdoor zone				
Proportion of resting behaviour				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	37.8784	2843	25.20266	.47267
Enriched	29.3445	2576	26.62174	.52452
Outer range	10.0200	1378	19.49794	.52525
Total	28.9962	6797	26.78151	.32485

Pairwise Comparisons						
Dependent Variable: Proportion of resting behaviour						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound
Apron	Enriched	8.802[*,b]	.861	.000	6.741	10.864
	Outer range	28.451[*,b]	1.053	.000	25.929	30.973
Enriched	Apron	-8.802[*,c]	.861	.000	-10.864	-6.741

	Outer range	19.649*,b,c	1.197	.000	16.782	22.515
Outer range	Apron	-28.451*,c	1.053	.000	-30.973	-25.929
	Enriched	-19.649*,b,c	1.197	.000	-22.515	-16.782
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. An estimate of the modified population marginal mean (J).						
c. An estimate of the modified population marginal mean (I).						
d. Adjustment for multiple comparisons: Bonferroni.						

Week of access

Proportion of resting behaviour * Week of outdoor access				
Proportion of resting behaviour				
Week of outdoor access	Mean	N	Std. Deviation	Std. Error of Mean
Week1	52.3485	198	29.82953	2.11989
Week2	42.2034	208	24.94052	1.72931
Week3	38.9333	400	25.90177	1.29509
Week4	32.5460	417	25.35416	1.24160
Week5	25.2239	439	24.37328	1.16327
Week6	29.7396	429	24.82447	1.19854
Week7	27.1372	425	24.40701	1.18391
Week8	30.2165	462	26.93634	1.25319
Week9	20.5904	522	25.22644	1.10413
Week10	24.7067	597	25.50185	1.04372
Week11	30.2987	474	27.12871	1.24606
Week12	28.7339	516	28.25946	1.24405
Week13	23.4767	557	25.16170	1.06614
Week14	25.4435	586	26.56307	1.09731
Week15	29.6317	567	26.91323	1.13025
Total	28.9962	6797	26.78151	.32485

Interactions

Zone X Week of access

ANOVA
Proportion of resting behaviour

Week of outdoor access		Sum of Squares	df	Mean Square	F	Sig.
Week3	Between Groups	13302.162	1	13302.162	20.812	.000
	Within Groups	254387.546	398	639.165		
	Total	267689.708	399			
Week4	Between Groups	15996.896	2	7998.448	13.171	.000
	Within Groups	251421.860	414	607.299		
	Total	267418.756	416			
Week5	Between Groups	29682.063	2	14841.031	28.071	.000
	Within Groups	230514.816	436	528.704		
	Total	260196.879	438			
Week6	Between Groups	25285.185	2	12642.593	22.584	.000
	Within Groups	238471.621	426	559.793		
	Total	263756.806	428			
Week7	Between Groups	14019.412	2	7009.706	12.400	.000
	Within Groups	238558.281	422	565.304		
	Total	252577.693	424			
Week8	Between Groups	54352.778	2	27176.389	44.529	.000
	Within Groups	280133.357	459	610.312		
	Total	334486.135	461			
Week9	Between Groups	76113.040	2	38056.520	77.324	.000
	Within Groups	255437.552	519	492.173		
	Total	331550.592	521			
Week10	Between Groups	91547.467	2	45773.734	91.839	.000
	Within Groups	296057.846	594	498.414		
	Total	387605.313	596			
Week11	Between Groups	37711.280	2	18855.640	28.611	.000
	Within Groups	310400.980	471	659.025		
	Total	348112.259	473			
Week12	Between Groups	69169.199	2	34584.599	51.860	.000
	Within Groups	342108.338	513	666.878		
	Total	411277.536	515			
Week13	Between Groups	49795.353	2	24897.676	45.641	.000
	Within Groups	302214.324	554	545.513		
	Total	352009.677	556			
Week14	Between Groups	64112.495	2	32056.247	53.602	.000
	Within Groups	348661.686	583	598.047		
	Total	412774.180	585			
Week15	Between Groups	76269.060	2	38134.530	64.453	.000

	Within Groups	333697.069	564	591.661		
	Total	409966.129	566			

Multiple Comparisons							
Dependent Variable: Proportion of resting behaviour							
Bonferroni							
Week of outdoor access	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Week4	Apron	Enriched	4.09150	2.46434	.293	-1.8322	10.0152
		Outer range	31.68235*	6.22575	.000	16.7172	46.6475
	Enriched	Apron	-4.09150	2.46434	.293	-10.0152	1.8322
		Outer range	27.59085*	6.22575	.000	12.6257	42.5560
	Outer range	Apron	-31.68235*	6.22575	.000	-46.6475	-16.7172
		Enriched	-27.59085*	6.22575	.000	-42.5560	-12.6257
Week5	Apron	Enriched	11.00000*	2.29936	.000	5.4741	16.5259
		Outer range	27.74359*	4.02493	.000	18.0707	37.4165
	Enriched	Apron	-11.00000*	2.29936	.000	-16.5259	-5.4741
		Outer range	16.74359*	4.02493	.000	7.0707	26.4165
	Outer range	Apron	-27.74359*	4.02493	.000	-37.4165	-18.0707
		Enriched	-16.74359*	4.02493	.000	-26.4165	-7.0707
Week6	Apron	Enriched	10.89150*	2.36599	.000	5.2049	16.5781
		Outer range	27.72598*	4.70129	.000	16.4266	39.0254
	Enriched	Apron	-10.89150*	2.36599	.000	-16.5781	-5.2049
		Outer range	16.83448*	4.70129	.001	5.5351	28.1339
	Outer range	Apron	-27.72598*	4.70129	.000	-39.0254	-16.4266
		Enriched	-16.83448*	4.70129	.001	-28.1339	-5.5351
Week7	Apron	Enriched	10.11650*	2.37761	.000	4.4018	15.8312
		Outer range	17.74150*	5.04368	.001	5.6187	29.8643
	Enriched	Apron	-10.11650*	2.37761	.000	-15.8312	-4.4018
		Outer range	7.62500	5.04368	.394	-4.4978	19.7478
	Outer range	Apron	-17.74150*	5.04368	.001	-29.8643	-5.6187
		Enriched	-7.62500	5.04368	.394	-19.7478	4.4978
Week8	Apron	Enriched	6.03849*	2.48293	.046	.0725	12.0044
		Outer range	32.98399*	3.51357	.000	24.5416	41.4264
	Enriched	Apron	-6.03849*	2.48293	.046	-12.0044	-.0725

		Outer range	26.94550*	3.50914	.000	18.5138	35.3772
	Outer range	Apron	-32.98399*	3.51357	.000	-41.4264	-24.5416
		Enriched	-26.94550*	3.50914	.000	-35.3772	-18.5138
Week9	Apron	Enriched	-1.53719	2.47509	1.000	-7.4818	4.4074
		Outer range	24.00771*	2.39883	.000	18.2463	29.7691
	Enriched	Apron	1.53719	2.47509	1.000	-4.4074	7.4818
		Outer range	25.54489*	2.30611	.000	20.0061	31.0836
	Outer range	Apron	-24.00771*	2.39883	.000	-29.7691	-18.2463
		Enriched	-25.54489*	2.30611	.000	-31.0836	-20.0061
Week10	Apron	Enriched	-6.78392*	2.23812	.008	-12.1572	-1.4107
		Outer range	22.21156*	2.23812	.000	16.8383	27.5848
	Enriched	Apron	6.78392*	2.23812	.008	1.4107	12.1572
		Outer range	28.99548*	2.23812	.000	23.6222	34.3687
	Outer range	Apron	-22.21156*	2.23812	.000	-27.5848	-16.8383
		Enriched	-28.99548*	2.23812	.000	-34.3687	-23.6222
Week11	Apron	Enriched	8.56650*	2.56715	.003	2.3988	14.7342
		Outer range	26.33716*	3.49298	.000	17.9451	34.7293
	Enriched	Apron	-8.56650*	2.56715	.003	-14.7342	-2.3988
		Outer range	17.77066*	3.49298	.000	9.3786	26.1628
	Outer range	Apron	-26.33716*	3.49298	.000	-34.7293	-17.9451
		Enriched	-17.77066*	3.49298	.000	-26.1628	-9.3786
Week12	Apron	Enriched	5.48611	2.69703	.127	-.9918	11.9640
		Outer range	28.09308*	2.90850	.000	21.1073	35.0789
	Enriched	Apron	-5.48611	2.69703	.127	-11.9640	.9918
		Outer range	22.60697*	2.80851	.000	15.8613	29.3526
	Outer range	Apron	-28.09308*	2.90850	.000	-35.0789	-21.1073
		Enriched	-22.60697*	2.80851	.000	-29.3526	-15.8613
Week13	Apron	Enriched	2.97564	2.42043	.658	-2.8365	8.7878
		Outer range	21.54673*	2.46945	.000	15.6169	27.4765
	Enriched	Apron	-2.97564	2.42043	.658	-8.7878	2.8365
		Outer range	18.57108*	2.39212	.000	12.8270	24.3152
	Outer range	Apron	-21.54673*	2.46945	.000	-27.4765	-15.6169
		Enriched	-18.57108*	2.39212	.000	-24.3152	-12.8270
Week14	Apron	Enriched	11.69137*	2.49066	.000	5.7115	17.6712
		Outer range	25.69032*	2.48764	.000	19.7177	31.6629
	Enriched	Apron	-11.69137*	2.49066	.000	-17.6712	-5.7115
		Outer range	13.99895*	2.44857	.000	8.1202	19.8777
	Outer range	Apron	-25.69032*	2.48764	.000	-31.6629	-19.7177
		Enriched	-13.99895*	2.44857	.000	-19.8777	-8.1202

Week15	Apron	Enriched	15.25445*	2.54852	.000	9.1351	21.3738
		Outer range	28.89707*	2.54560	.000	22.7847	35.0094
	Enriched	Apron	-15.25445*	2.54852	.000	-21.3738	-9.1351
		Outer range	13.64262*	2.43546	.000	7.7947	19.4905
	Outer range	Apron	-28.89707*	2.54560	.000	-35.0094	-22.7847
		Enriched	-13.64262*	2.43546	.000	-19.4905	-7.7947
*. The mean difference is significant at the 0.05 level.							

Week X Zone

ANOVA						
Proportion of resting behaviour						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	107506.898	14	7679.064	12.792	.000
	Within Groups	1697658.181	2828	600.303		
	Total	1805165.080	2842			
Enriched	Between Groups	43875.531	13	3375.041	4.855	.000
	Within Groups	1781070.492	2562	695.188		
	Total	1824946.023	2575			
Outer range	Between Groups	19326.688	11	1756.972	4.760	.000
	Within Groups	504166.694	1366	369.082		
	Total	523493.381	1377			

Appetitive/Foraging behaviour

Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of appetitive/Foraging behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	548067.843[a]	55	9964.870	15.714	.000
Intercept	6392.769	1	6392.769	10.081	.002
Zone	136214.969	2	68107.485	107.402	.000
Week	93674.188	14	6691.013	10.551	.000
Time	13523.128	4	3380.782	5.331	.000

RH	52.925	1	52.925	.083	.773
Temp	468.025	1	468.025	.738	.390
Wind	795.763	1	795.763	1.255	.263
Zone * Week	70925.014	24	2955.209	4.660	.000
Zone * Time	8208.896	8	1026.112	1.618	.114
Error	4274693.684	6741	634.133		
Total	12158716.810	6797			
Corrected Total	4822761.527	6796			
a. R Squared = .114 (Adjusted R Squared = .106)					

Step 2

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of appetitive+Foraging behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	539858.947[a]	47	11486.361	18.100	.000
Intercept	6308.279	1	6308.279	9.941	.002
Zone	140186.339	2	70093.169	110.453	.000
Week	94049.131	14	6717.795	10.586	.000
Time	10853.947	4	2713.487	4.276	.002
RH	46.293	1	46.293	.073	.787
Temp	329.995	1	329.995	.520	.471
Wind	355.098	1	355.098	.560	.454
Zone * Week	71039.888	24	2959.995	4.664	.000
Error	4282902.580	6749	634.598		
Total	12158716.810	6797			
Corrected Total	4822761.527	6796			
a. R Squared = .112 (Adjusted R Squared = .106)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of appetitive+Foraging behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	539503.849[a]	46	11728.345	18.483	.000
Intercept	9155.260	1	9155.260	14.428	.000

Zone	150128.306	2	75064.153	118.294	.000
Week	93711.654	14	6693.690	10.549	.000
Time	10971.207	4	2742.802	4.322	.002
RH	.060	1	.060	.000	.992
Temp	500.448	1	500.448	.789	.375
Zone * Week	70766.808	24	2948.617	4.647	.000
Error	4283257.677	6750	634.557		
Total	12158716.810	6797			
Corrected Total	4822761.527	6796			
a. R Squared = .112 (Adjusted R Squared = .106)					

Step 4

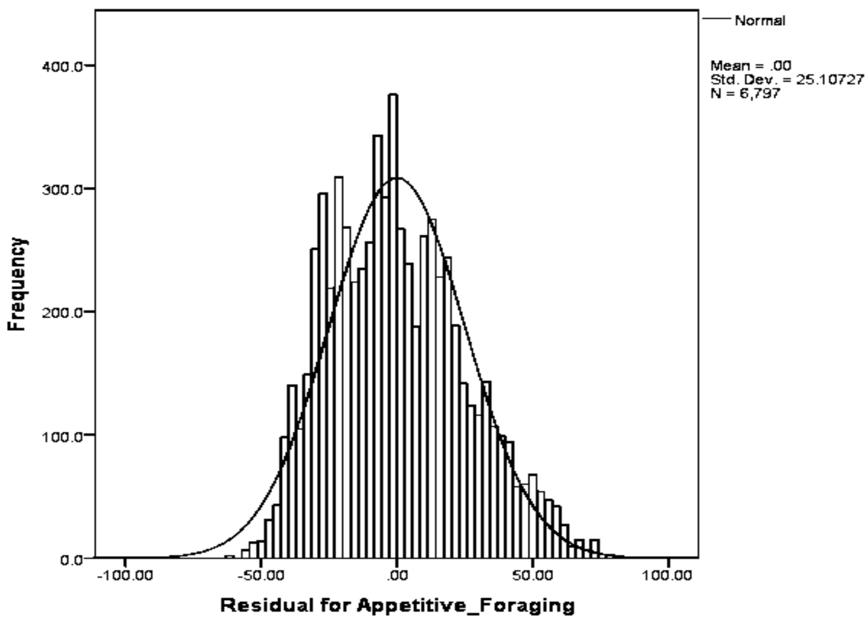
Tests of Between-Subjects Effects					
Dependent Variable: Proportion of appetitive+Foraging behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	539003.401[a]	45	11977.853	18.877	.000
Intercept	25617.950	1	25617.950	40.373	.000
Zone	150444.653	2	75222.327	118.547	.000
Week	102982.527	14	7355.895	11.593	.000
Time	11109.286	4	2777.322	4.377	.002
RH	269.645	1	269.645	.425	.515
Zone * Week	70968.750	24	2957.031	4.660	.000
Error	4283758.126	6751	634.537		
Total	12158716.810	6797			
Corrected Total	4822761.527	6796			
a. R Squared = .112 (Adjusted R Squared = .106)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of appetitive+Foraging behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	538733.756[a]	44	12243.949	19.298	.000
Intercept	3338424.907	1	3338424.907	5261.648	.000
Zone	177244.141	2	88622.070	139.676	.000
Week	119627.573	14	8544.827	13.467	.000

Time	11228.810	4	2807.203	4.424	.001
Zone * Week	73021.419	24	3042.559	4.795	.000
Error	4284027.771	6752	634.483		
Total	12158716.810	6797			
Corrected Total	4822761.527	6796			
a. R Squared = .112 (Adjusted R Squared = .106)					

Normal distribution curve for appetitive+foraging residual



Main effects

Zone

Proportion of appetitive+Foraging behaviour * Outdoor zone				
Proportion of appetitive+Foraging behaviour				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	25.6056	2843	22.94644	.43035
Enriched	34.8667	2576	25.45369	.50151
Outer range	44.0392	1378	31.02949	.83589
Total	32.8526	6797	26.63920	.32312

Pairwise Comparisons						
Dependent Variable: Proportion of appetitive+Foraging behaviour						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound
Apron	Enriched	-9.605*,b	.894	.000	-11.746	-7.464
	Outer range	-18.419*,b	1.104	.000	-21.063	-15.776
Enriched	Apron	9.605*,c	.894	.000	7.464	11.746
	Outer range	-8.814*,b,c	1.249	.000	-11.805	-5.824
Outer range	Apron	18.419*,c	1.104	.000	15.776	21.063
	Enriched	8.814*,b,c	1.249	.000	5.824	11.805
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. An estimate of the modified population marginal mean (J).						
c. An estimate of the modified population marginal mean (I).						
d. Adjustment for multiple comparisons: Bonferroni.						

Time of the day

Proportion of appetitive+Foraging behaviour * Time of the day				
Proportion of appetitive+Foraging behaviour				
Time of the day	Mean	N	Std. Deviation	Std. Error of Mean
9am	31.7664	1485	26.85568	.69690
10am	31.5328	1432	26.60023	.70293
11am	32.9334	1375	26.43351	.71286
1pm	34.2993	1304	26.58803	.73629
2pm	34.1061	1201	26.61259	.76792
Total	32.8526	6797	26.63920	.32312

Pairwise Comparisons					
Dependent Variable: Proportion of appetitive+Foraging behaviour					
(I) Time of the day	(J) Time of the day	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]

					Lower Bound	Upper Bound
9am	10am	-.237[a,b]	.939	1.000	-2.874	2.401
	11am	-2.021[a,b]	.954	.341	-4.698	.657
	1pm	-3.183[a,b,*]	.968	.010	-5.902	-.465
	2pm	-2.764[a,b]	.992	.053	-5.549	.021
10am	9am	.237[a,b]	.939	1.000	-2.401	2.874
	11am	-1.784[a,b]	.954	.614	-4.461	.893
	1pm	-2.946[a,b,*]	.968	.023	-5.665	-.228
	2pm	-2.528[a,b]	.992	.109	-5.313	.258
11am	9am	2.021[a,b]	.954	.341	-.657	4.698
	10am	1.784[a,b]	.954	.614	-.893	4.461
	1pm	-1.162[a,b]	.975	1.000	-3.899	1.575
	2pm	-.744[a,b]	.999	1.000	-3.548	2.061
1pm	9am	3.183[a,b,*]	.968	.010	.465	5.902
	10am	2.946[a,b,*]	.968	.023	.228	5.665
	11am	1.162[a,b]	.975	1.000	-1.575	3.899
	2pm	.419[a,b]	1.009	1.000	-2.414	3.252
2pm	9am	2.764[a,b]	.992	.053	-.021	5.549
	10am	2.528[a,b]	.992	.109	-.258	5.313
	11am	.744[a,b]	.999	1.000	-2.061	3.548
	1pm	-.419[a,b]	1.009	1.000	-3.252	2.414
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
a. An estimate of the modified population marginal mean (I).						
b. An estimate of the modified population marginal mean (J).						
d. Adjustment for multiple comparisons: Bonferroni.						

Week of outdoor access

Proportion of appetitive+Foraging behaviour * Week of outdoor access				
Proportion of appetitive+Foraging behaviour				
Week of outdoor access	Mean	N	Std. Deviation	Std. Error of Mean
Week1	30.9934	198	27.12553	1.92773
Week2	28.1971	208	25.48552	1.76710
Week3	21.9918	400	24.07403	1.20370
Week4	33.5494	417	24.75783	1.21240
Week5	37.6651	439	26.03989	1.24282

Week6	33.5119	429	25.20851	1.21708
Week7	31.2313	425	23.08589	1.11983
Week8	28.8312	462	25.08683	1.16715
Week9	33.0904	522	27.83839	1.21845
Week10	35.7508	597	25.29845	1.03540
Week11	26.3814	474	25.69505	1.18021
Week12	28.2911	516	25.90412	1.14037
Week13	38.2792	557	28.52926	1.20882
Week14	39.3543	586	28.34238	1.17081
Week15	36.8663	567	28.16682	1.18290
Total	32.8526	6797	26.63920	.32312

Interactions

Zone X Week

ANOVA						
Proportion of appetitive+Foraging behaviour						
Week of outdoor access		Sum of Squares	df	Mean Square	F	Sig.
Week3	Between Groups	15335.107	1	15335.107	28.268	.000
	Within Groups	215908.956	398	542.485		
	Total	231244.063	399			
Week4	Between Groups	16227.797	2	8113.898	14.069	.000
	Within Groups	238759.406	414	576.714		
	Total	254987.202	416			
Week5	Between Groups	19750.802	2	9875.401	15.530	.000
	Within Groups	277246.534	436	635.887		
	Total	296997.337	438			
Week6	Between Groups	18075.996	2	9037.998	15.164	.000
	Within Groups	253904.774	426	596.021		
	Total	271980.769	428			
Week7	Between Groups	11848.668	2	5924.334	11.676	.000
	Within Groups	214125.666	422	507.407		
	Total	225974.334	424			
Week8	Between Groups	14888.134	2	7444.067	12.414	.000
	Within Groups	275241.817	459	599.655		
	Total	290129.951	461			
Week9	Between Groups	35963.444	2	17981.722	25.374	.000
	Within Groups	367799.109	519	708.669		

	Total	403762.552	521			
Week10	Between Groups	4116.925	2	2058.463	3.240	.040
	Within Groups	377329.827	594	635.235		
	Total	381446.752	596			
Week11	Between Groups	10736.218	2	5368.109	8.384	.000
	Within Groups	301555.339	471	640.245		
	Total	312291.557	473			
Week12	Between Groups	28701.862	2	14350.931	23.233	.000
	Within Groups	316875.337	513	617.691		
	Total	345577.199	515			
Week13	Between Groups	48194.066	2	24097.033	33.016	.000
	Within Groups	404344.873	554	729.864		
	Total	452538.938	556			
Week14	Between Groups	88731.585	2	44365.793	67.853	.000
	Within Groups	381193.309	583	653.848		
	Total	469924.894	585			
Week15	Between Groups	56165.494	2	28082.747	40.314	.000
	Within Groups	392881.713	564	696.599		
	Total	449047.207	566			

Multiple Comparisons

Dependent Variable: Proportion of appetitive+Foraging behaviour

Bonferroni

Week of outdoor access	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Week4	Apron	Enriched	-6.03350*	2.40149	.037	-11.8061	-.2609
		Outer range	-30.80000*	6.06695	.000	-45.3834	-16.2166
	Enriched	Apron	6.03350*	2.40149	.037	.2609	11.8061
		Outer range	-24.76650*	6.06695	.000	-39.3499	-10.1831
	Outer range	Apron	30.80000*	6.06695	.000	16.2166	45.3834
		Enriched	24.76650*	6.06695	.000	10.1831	39.3499
Week5	Apron	Enriched	-11.20000*	2.52168	.000	-17.2602	-5.1398
		Outer range	-19.84103*	4.41409	.000	-30.4492	-9.2328
	Enriched	Apron	11.20000*	2.52168	.000	5.1398	17.2602
		Outer range	-8.64103	4.41409	.153	-19.2492	1.9672

	Outer range	Apron	19.84103*	4.41409	.000	9.2328	30.4492
		Enriched	8.64103	4.41409	.153	-1.9672	19.2492
Week6	Apron	Enriched	-12.67500*	2.44135	.000	-18.5427	-6.8073
		Outer range	-14.96022*	4.85103	.007	-26.6196	-3.3009
	Enriched	Apron	12.67500*	2.44135	.000	6.8073	18.5427
		Outer range	-2.28522	4.85103	1.000	-13.9446	9.3741
	Outer range	Apron	14.96022*	4.85103	.007	3.3009	26.6196
		Enriched	2.28522	4.85103	1.000	-9.3741	13.9446
Week7	Apron	Enriched	-10.88350*	2.25257	.000	-16.2977	-5.4693
		Outer range	-5.83350	4.77842	.669	-17.3187	5.6517
	Enriched	Apron	10.88350*	2.25257	.000	5.4693	16.2977
		Outer range	5.05000	4.77842	.874	-6.4352	16.5352
	Outer range	Apron	5.83350	4.77842	.669	-5.6517	17.3187
		Enriched	-5.05000	4.77842	.874	-16.5352	6.4352
Week8	Apron	Enriched	-10.72193*	2.46115	.000	-16.6356	-4.8083
		Outer range	-13.26203*	3.48276	.000	-21.6304	-4.8937
	Enriched	Apron	10.72193*	2.46115	.000	4.8083	16.6356
		Outer range	-2.54010	3.47837	1.000	-10.8979	5.8177
	Outer range	Apron	13.26203*	3.48276	.000	4.8937	21.6304
		Enriched	2.54010	3.47837	1.000	-5.8177	10.8979
Week9	Apron	Enriched	4.16455	2.96998	.484	-2.9687	11.2978
		Outer range	-14.52496*	2.87847	.000	-21.4384	-7.6115
	Enriched	Apron	-4.16455	2.96998	.484	-11.2978	2.9687
		Outer range	-18.68951*	2.76722	.000	-25.3357	-12.0433
	Outer range	Apron	14.52496*	2.87847	.000	7.6115	21.4384
		Enriched	18.68951*	2.76722	.000	12.0433	25.3357
Week10	Apron	Enriched	-5.17588	2.52671	.123	-11.2420	.8902
		Outer range	-5.89548	2.52671	.060	-11.9616	.1706
	Enriched	Apron	5.17588	2.52671	.123	-.8902	11.2420
		Outer range	-.71960	2.52671	1.000	-6.7857	5.3465
	Outer range	Apron	5.89548	2.52671	.060	-.1706	11.9616
		Enriched	.71960	2.52671	1.000	-5.3465	6.7857
Week11	Apron	Enriched	-9.34150*	2.53031	.001	-15.4207	-3.2623
		Outer range	-10.34392*	3.44285	.008	-18.6156	-2.0723
	Enriched	Apron	9.34150*	2.53031	.001	3.2623	15.4207
		Outer range	-1.00242	3.44285	1.000	-9.2741	7.2692
	Outer range	Apron	10.34392*	3.44285	.008	2.0723	18.6156
		Enriched	1.00242	3.44285	1.000	-7.2692	9.2741
Week12	Apron	Enriched	-6.22084	2.59566	.051	-12.4552	.0136

		Outer range	-18.82365*	2.79919	.000	-25.5469	-12.1004
	Enriched	Apron	6.22084	2.59566	.051	-.0136	12.4552
		Outer range	-12.60281*	2.70295	.000	-19.0949	-6.1107
	Outer range	Apron	18.82365*	2.79919	.000	12.1004	25.5469
		Enriched	12.60281*	2.70295	.000	6.1107	19.0949
Week13	Apron	Enriched	-11.17291*	2.79970	.000	-17.8958	-4.4501
		Outer range	-23.19656*	2.85639	.000	-30.0555	-16.3376
	Enriched	Apron	11.17291*	2.79970	.000	4.4501	17.8958
		Outer range	-12.02365*	2.76695	.000	-18.6678	-5.3795
	Outer range	Apron	23.19656*	2.85639	.000	16.3376	30.0555
		Enriched	12.02365*	2.76695	.000	5.3795	18.6678
Week14	Apron	Enriched	-17.14270*	2.60426	.000	-23.3953	-10.8901
		Outer range	-30.24994*	2.60111	.000	-36.4950	-24.0049
	Enriched	Apron	17.14270*	2.60426	.000	10.8901	23.3953
		Outer range	-13.10724*	2.56026	.000	-19.2542	-6.9603
	Outer range	Apron	30.24994*	2.60111	.000	24.0049	36.4950
		Enriched	13.10724*	2.56026	.000	6.9603	19.2542
Week15	Apron	Enriched	-17.96301*	2.76531	.000	-24.6029	-11.3231
		Outer range	-24.12093*	2.76214	.000	-30.7532	-17.4886
	Enriched	Apron	17.96301*	2.76531	.000	11.3231	24.6029
		Outer range	-6.15792	2.64263	.060	-12.5032	.1874
	Outer range	Apron	24.12093*	2.76214	.000	17.4886	30.7532
		Enriched	6.15792	2.64263	.060	-.1874	12.5032
*. The mean difference is significant at the 0.05 level.							

Week X Zone

ANOVA						
Proportion of appetitive+Foraging behaviour						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	58718.940	14	4194.210	8.250	.000
	Within Groups	1437704.652	2828	508.382		
	Total	1496423.592	2842			
Enriched	Between Groups	73890.400	13	5683.877	9.133	.000

	Within Groups	1594426.586	2562	622.337		
	Total	1668316.986	2575			
Outer range	Between Groups	62690.441	11	5699.131	6.163	.000
	Within Groups	1263125.343	1366	924.689		
	Total	1325815.784	1377			

Locomotory behaviour

Step 1

Tests of Between-Subjects Effects

Dependent Variable: Proportion of locomotory behaviour

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	430215.923[a]	55	7822.108	12.541	.000
Intercept	2675.663	1	2675.663	4.290	.038
Zone	55977.514	2	27988.757	44.873	.000
Week	151244.940	14	10803.210	17.320	.000
Time	7062.891	4	1765.723	2.831	.023
RH	367.064	1	367.064	.589	.443
Temp	1117.682	1	1117.682	1.792	.181
Wind	430.822	1	430.822	.691	.406
Zone * Week	70155.761	24	2923.157	4.687	.000
Zone * Time	5774.430	8	721.804	1.157	.321
Error	4204537.395	6741	623.726		
Total	13602392.370	6797			
Corrected Total	4634753.318	6796			

a. R Squared = .093 (Adjusted R Squared = .085)

Step 2

Tests of Between-Subjects Effects

Dependent Variable: Proportion of locomotory behaviour

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	424441.494[a]	47	9030.670	14.476	.000
Intercept	2680.968	1	2680.968	4.298	.038
Zone	68723.693	2	34361.846	55.081	.000
Week	151547.169	14	10824.798	17.352	.000

Time	4700.147	4	1175.037	1.884	.110
RH	407.906	1	407.906	.654	.419
Temp	1026.017	1	1026.017	1.645	.200
Wind	803.129	1	803.129	1.287	.257
Zone * Week	71079.551	24	2961.648	4.747	.000
Error	4210311.824	6749	623.842		
Total	13602392.370	6797			
Corrected Total	4634753.318	6796			
a. R Squared = .092 (Adjusted R Squared = .085)					

Step 3

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of locomotory behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	423638.365[a]	46	9209.530	14.762	.000
Intercept	4849.078	1	4849.078	7.773	.005
Zone	77577.895	2	38788.947	62.175	.000
Week	153433.873	14	10959.562	17.567	.000
Time	4701.663	4	1175.416	1.884	.110
RH	107.585	1	107.585	.172	.678
Temp	724.849	1	724.849	1.162	.281
Zone * Week	72140.084	24	3005.837	4.818	.000
Error	4211114.953	6750	623.869		
Total	13602392.370	6797			
Corrected Total	4634753.318	6796			
a. R Squared = .091 (Adjusted R Squared = .085)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of locomotory behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	422913.516[a]	45	9398.078	15.064	.000
Intercept	38638.452	1	38638.452	61.932	.000
Zone	77049.390	2	38524.695	61.750	.000

Week	156297.562	14	11164.112	17.895	.000
Time	4789.482	4	1197.370	1.919	.104
RH	51.534	1	51.534	.083	.774
Zone * Week	71418.080	24	2975.753	4.770	.000
Error	4211839.802	6751	623.884		
Total	13602392.370	6797			
Corrected Total	4634753.318	6796			
a. R Squared = .091 (Adjusted R Squared = .085)					

Step 5

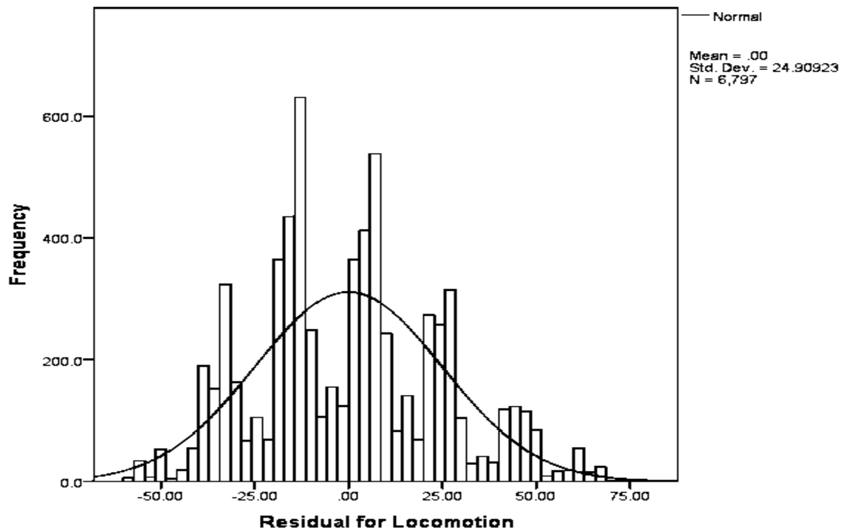
Tests of Between-Subjects Effects					
Dependent Variable: Proportion of locomotory behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	422861.982[a]	44	9610.500	15.406	.000
Intercept	3849476.446	1	3849476.446	6171.020	.000
Zone	77044.893	2	38522.446	61.755	.000
Week	171097.373	14	12221.241	19.592	.000
Time	4821.193	4	1205.298	1.932	.102
Zone * Week	71434.824	24	2976.451	4.771	.000
Error	4211891.336	6752	623.799		
Total	13602392.370	6797			
Corrected Total	4634753.318	6796			
a. R Squared = .091 (Adjusted R Squared = .085)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of locomotory behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	418040.789[a]	40	10451.020	16.745	.000
Intercept	3988386.370	1	3988386.370	6390.177	.000
Zone	82269.145	2	41134.572	65.906	.000
Week	172621.170	14	12330.084	19.755	.000
Zone * Week	72673.595	24	3028.066	4.852	.000
Error	4216712.529	6756	624.143		

Total	13602392.370	6797			
Corrected Total	4634753.318	6796			
a. R Squared = .090 (Adjusted R Squared = .085)					

Normal distribution for locomotion residual



Main effects

Zone

Proportion of locomotory behaviour * Outdoor zone				
Proportion of locomotory behaviour				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	33.1170	2843	23.06653	.43261
Enriched	34.7800	2576	24.30829	.47894
Outer range	45.8213	1378	32.35379	.87157
Total	36.3229	6797	26.11480	.31676

Pairwise Comparisons						
Dependent Variable: Proportion of locomotory behaviour						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound

Apron	Enriched	-1.214[a]	.886	.512	-3.336	.907
	Outer range	-13.718[a,*]	1.084	.000	-16.313	-11.123
Enriched	Apron	1.214[c]	.886	.512	-.907	3.336
	Outer range	-12.503[a,*,c]	1.232	.000	-15.453	-9.554
Outer range	Apron	13.718[*,c]	1.084	.000	11.123	16.313
	Enriched	12.503[a,*,c]	1.232	.000	9.554	15.453
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
a. An estimate of the modified population marginal mean (J).						
c. An estimate of the modified population marginal mean (I).						
d. Adjustment for multiple comparisons: Bonferroni.						

Week of access

Proportion of locomotory behaviour * Week of outdoor access				
Proportion of locomotory behaviour				
Week of outdoor access	Mean	N	Std. Deviation	Std. Error of Mean
Week1	15.6480	198	19.17747	1.36288
Week2	24.9841	208	20.22385	1.40227
Week3	35.8750	400	22.86463	1.14323
Week4	31.4106	417	21.74972	1.06509
Week5	35.2884	439	22.73417	1.08504
Week6	34.6154	429	23.86534	1.15223
Week7	38.0431	425	25.29543	1.22701
Week8	38.5859	462	26.38536	1.22756
Week9	45.5655	522	28.42432	1.24410
Week10	38.0012	597	27.94980	1.14391
Week11	42.3914	474	26.90597	1.23583
Week12	42.1221	516	28.58441	1.25836
Week13	37.0585	557	26.17189	1.10894
Week14	33.7341	586	25.42945	1.05048
Week15	31.9166	567	25.83611	1.08501
Total	36.3229	6797	26.11480	.31676

Interactions
Zone X Week

ANOVA						
Proportion of locomotory behaviour						
Week of outdoor access		Sum of Squares	df	Mean Square	F	Sig.
Week3	Between Groups	.250	1	.250	.000	.983
	Within Groups	208593.500	398	524.104		
	Total	208593.750	399			
Week4	Between Groups	481.662	2	240.831	.508	.602
	Within Groups	196307.212	414	474.172		
	Total	196788.874	416			
Week5	Between Groups	3877.531	2	1938.765	3.799	.023
	Within Groups	222499.520	436	510.320		
	Total	226377.051	438			
Week6	Between Groups	4829.595	2	2414.798	4.305	.014
	Within Groups	238939.723	426	560.891		
	Total	243769.318	428			
Week7	Between Groups	7873.426	2	3936.713	6.306	.002
	Within Groups	263426.656	422	624.234		
	Total	271300.082	424			
Week8	Between Groups	35548.715	2	17774.358	28.587	.000
	Within Groups	285393.703	459	621.773		
	Total	320942.419	461			
Week9	Between Groups	10231.430	2	5115.715	6.465	.002
	Within Groups	410706.429	519	791.342		
	Total	420937.859	521			
Week10	Between Groups	85778.120	2	42889.060	67.076	.000
	Within Groups	379811.809	594	639.414		
	Total	465589.929	596			
Week11	Between Groups	19118.519	2	9559.260	13.926	.000
	Within Groups	323300.895	471	686.414		
	Total	342419.415	473			
Week12	Between Groups	11965.622	2	5982.811	7.507	.001
	Within Groups	408824.586	513	796.929		
	Total	420790.208	515			
Week13	Between Groups	5061.086	2	2530.543	3.731	.025
	Within Groups	375781.066	554	678.305		
	Total	380842.152	556			
Week14	Between Groups	100.412	2	50.206	.077	.926
	Within Groups	378193.805	583	648.703		

	Total	378294.217	585			
Week15	Between Groups	9786.139	2	4893.069	7.499	.001
	Within Groups	368021.365	564	652.520		
	Total	377807.504	566			

Multiple Comparisons

Dependent Variable: Proportion of locomotory behaviour

Bonferroni

Week of outdoor access	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Week4	Apron	Enriched	-1.25800	2.17755	1.000	-6.4923	3.9763
		Outer range	-5.08235	5.50121	1.000	-18.3059	8.1412
	Enriched	Apron	1.25800	2.17755	1.000	-3.9763	6.4923
		Outer range	-3.82435	5.50121	1.000	-17.0479	9.3992
	Outer range	Apron	5.08235	5.50121	1.000	-8.1412	18.3059
		Enriched	3.82435	5.50121	1.000	-9.3992	17.0479
Week5	Apron	Enriched	-1.80000	2.25903	1.000	-7.2290	3.6290
		Outer range	-10.90000*	3.95433	.018	-20.4033	-1.3967
	Enriched	Apron	1.80000	2.25903	1.000	-3.6290	7.2290
		Outer range	-9.10000	3.95433	.066	-18.6033	.4033
	Outer range	Apron	10.90000*	3.95433	.018	1.3967	20.4033
		Enriched	9.10000	3.95433	.066	-.4033	18.6033
Week6	Apron	Enriched	-.24200	2.36831	1.000	-5.9342	5.4502
		Outer range	-13.47747*	4.70590	.013	-24.7880	-2.1670
	Enriched	Apron	.24200	2.36831	1.000	-5.4502	5.9342
		Outer range	-13.23547*	4.70590	.015	-24.5460	-1.9250
	Outer range	Apron	13.47747*	4.70590	.013	2.1670	24.7880
		Enriched	13.23547*	4.70590	.015	1.9250	24.5460
Week7	Apron	Enriched	-4.20850	2.49847	.279	-10.2137	1.7967
		Outer range	-18.20850*	5.30005	.002	-30.9475	-5.4695
	Enriched	Apron	4.20850	2.49847	.279	-1.7967	10.2137
		Outer range	-14.00000*	5.30005	.026	-26.7390	-1.2610
	Outer range	Apron	18.20850*	5.30005	.002	5.4695	30.9475
		Enriched	14.00000*	5.30005	.026	1.2610	26.7390
Week8	Apron	Enriched	2.56812	2.50613	.918	-3.4536	8.5898

		Outer range	-23.54582*	3.54641	.000	-32.0671	-15.0246
	Enriched	Apron	-2.56812	2.50613	.918	-8.5898	3.4536
		Outer range	-26.11394*	3.54193	.000	-34.6245	-17.6034
	Outer range	Apron	23.54582*	3.54641	.000	15.0246	32.0671
		Enriched	26.11394*	3.54193	.000	17.6034	34.6245
Week9	Apron	Enriched	-2.65356	3.13845	1.000	-10.1914	4.8842
		Outer range	-10.28107*	3.04174	.002	-17.5866	-2.9755
	Enriched	Apron	2.65356	3.13845	1.000	-4.8842	10.1914
		Outer range	-7.62751*	2.92418	.028	-14.6507	-.6043
	Outer range	Apron	10.28107*	3.04174	.002	2.9755	17.5866
		Enriched	7.62751*	2.92418	.028	.6043	14.6507
Week10	Apron	Enriched	8.04020*	2.53501	.005	1.9542	14.1262
		Outer range	-20.43568*	2.53501	.000	-26.5217	-14.3497
	Enriched	Apron	-8.04020*	2.53501	.005	-14.1262	-1.9542
		Outer range	-28.47588*	2.53501	.000	-34.5619	-22.3899
	Outer range	Apron	20.43568*	2.53501	.000	14.3497	26.5217
		Enriched	28.47588*	2.53501	.000	22.3899	34.5619
Week11	Apron	Enriched	-.62500	2.61995	1.000	-6.9196	5.6696
		Outer range	-17.79189*	3.56482	.000	-26.3566	-9.2272
	Enriched	Apron	.62500	2.61995	1.000	-5.6696	6.9196
		Outer range	-17.16689*	3.56482	.000	-25.7316	-8.6022
	Outer range	Apron	17.79189*	3.56482	.000	9.2272	26.3566
		Enriched	17.16689*	3.56482	.000	8.6022	25.7316
Week12	Apron	Enriched	-.20881	2.94830	1.000	-7.2902	6.8726
		Outer range	-10.77975*	3.17948	.002	-18.4164	-3.1431
	Enriched	Apron	.20881	2.94830	1.000	-6.8726	7.2902
		Outer range	-10.57094*	3.07017	.002	-17.9451	-3.1968
	Outer range	Apron	10.77975*	3.17948	.002	3.1431	18.4164
		Enriched	10.57094*	3.07017	.002	3.1968	17.9451
Week13	Apron	Enriched	5.28442	2.69900	.152	-1.1966	11.7655
		Outer range	-1.66339	2.75365	1.000	-8.2757	4.9489
	Enriched	Apron	-5.28442	2.69900	.152	-11.7655	1.1966
		Outer range	-6.94781*	2.66742	.028	-13.3530	-.5426
	Outer range	Apron	1.66339	2.75365	1.000	-4.9489	8.2757
		Enriched	6.94781*	2.66742	.028	.5426	13.3530
Week14	Apron	Enriched	.85341	2.59400	1.000	-5.3745	7.0814
		Outer range	-.03880	2.59085	1.000	-6.2592	6.1816
	Enriched	Apron	-.85341	2.59400	1.000	-7.0814	5.3745
		Outer range	-.89221	2.55016	1.000	-7.0149	5.2305

	Outer range	Apron	.03880	2.59085	1.000	-6.1816	6.2592
		Enriched	.89221	2.55016	1.000	-5.2305	7.0149
Week15	Apron	Enriched	-.29596	2.67639	1.000	-6.7223	6.1304
		Outer range	-8.85152*	2.67332	.003	-15.2706	-2.4325
	Enriched	Apron	.29596	2.67639	1.000	-6.1304	6.7223
		Outer range	-8.55557*	2.55765	.003	-14.6969	-2.4143
	Outer range	Apron	8.85152*	2.67332	.003	2.4325	15.2706
		Enriched	8.55557*	2.55765	.003	2.4143	14.6969
*. The mean difference is significant at the 0.05 level.							

Week X Zone

ANOVA						
Proportion of locomotive behaviour						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	110710.567	14	7907.898	15.958	.000
	Within Groups	1401418.043	2828	495.551		
	Total	1512128.609	2842			
Enriched	Between Groups	52384.959	13	4029.612	7.027	.000
	Within Groups	1469164.942	2562	573.445		
	Total	1521549.900	2575			
Outer range	Between Groups	95269.549	11	8660.868	8.789	.000
	Within Groups	1346129.544	1366	985.454		
	Total	1441399.093	1377			

Comfort behaviour

Step 1

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of comfort behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20638.228[a]	55	375.241	8.535	.000
Intercept	3.453	1	3.453	.079	.779
Zone	3998.881	2	1999.440	45.481	.000
Week	2713.971	14	193.855	4.410	.000

Time	107.637	4	26.909	.612	.654
RH	.238	1	.238	.005	.941
Temp	22.843	1	22.843	.520	.471
Wind	6.934	1	6.934	.158	.691
Zone * Week	3318.977	24	138.291	3.146	.000
Zone * Time	302.962	8	37.870	.861	.548
Error	296350.754	6741	43.962		
Total	339701.670	6797			
Corrected Total	316988.982	6796			
a. R Squared = .065 (Adjusted R Squared = .057)					

Step 2

Tests of Between-Subjects Effects

Dependent Variable: Proportion of comfort behaviour

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20335.266[a]	47	432.665	9.843	.000
Intercept	2.337	1	2.337	.053	.818
Zone	4098.236	2	2049.118	46.618	.000
Week	2728.570	14	194.898	4.434	.000
Time	219.226	4	54.807	1.247	.289
RH	.000	1	.000	.000	.999
Temp	22.776	1	22.776	.518	.472
Wind	2.240	1	2.240	.051	.821
Zone * Week	3317.161	24	138.215	3.144	.000
Error	296653.716	6749	43.955		
Total	339701.670	6797			
Corrected Total	316988.982	6796			
a. R Squared = .064 (Adjusted R Squared = .058)					

Step 3

Tests of Between-Subjects Effects

Dependent Variable: Proportion of comfort behaviour

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20333.026[a]	46	442.022	10.058	.000

Intercept	1.003	1	1.003	.023	.880
Zone	4272.007	2	2136.004	48.602	.000
Week	3047.347	14	217.668	4.953	.000
Time	220.122	4	55.031	1.252	.287
RH	.348	1	.348	.008	.929
Temp	26.776	1	26.776	.609	.435
Zone * Week	3315.785	24	138.158	3.144	.000
Error	296655.956	6750	43.949		
Total	339701.670	6797			
Corrected Total	316988.982	6796			
a. R Squared = .064 (Adjusted R Squared = .058)					

Step 4

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of comfort behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20306.251[a]	45	451.250	10.268	.000
Intercept	136.899	1	136.899	3.115	.078
Zone	4328.903	2	2164.451	49.252	.000
Week	3023.398	14	215.957	4.914	.000
Time	222.126	4	55.532	1.264	.282
RH	9.813	1	9.813	.223	.637
Zone * Week	3295.682	24	137.320	3.125	.000
Error	296682.731	6751	43.946		
Total	339701.670	6797			
Corrected Total	316988.982	6796			
a. R Squared = .064 (Adjusted R Squared = .058)					

Step 5

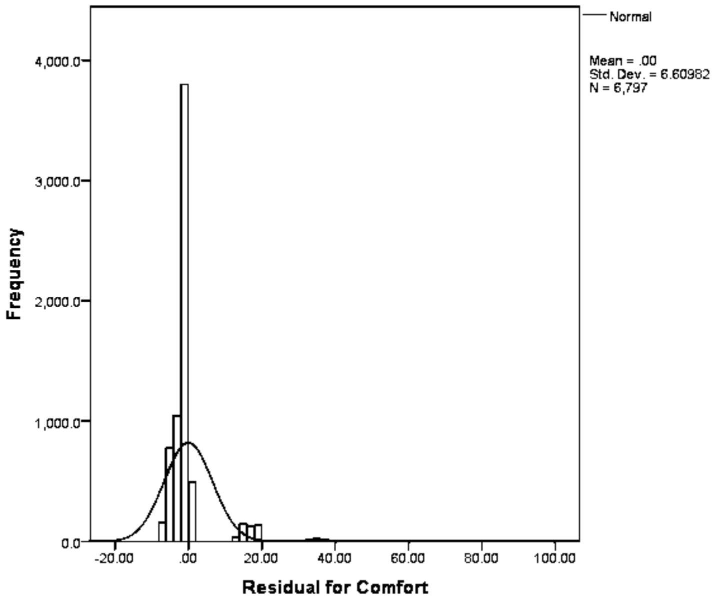
Tests of Between-Subjects Effects					
Dependent Variable: Proportion of comfort behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20296.438[a]	44	461.283	10.498	.000
Intercept	7902.531	1	7902.531	179.842	.000

Zone	5449.271	2	2724.636	62.006	.000
Week	3027.572	14	216.255	4.921	.000
Time	222.516	4	55.629	1.266	.281
Zone * Week	3286.074	24	136.920	3.116	.000
Error	296692.544	6752	43.941		
Total	339701.670	6797			
Corrected Total	316988.982	6796			
a. R Squared = .064 (Adjusted R Squared = .058)					

Fitted model

Tests of Between-Subjects Effects					
Dependent Variable: Proportion of comfort behaviour					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20073.921[a]	40	501.848	11.419	.000
Intercept	8031.481	1	8031.481	182.748	.000
Zone	5532.215	2	2766.107	62.940	.000
Week	3049.529	14	217.823	4.956	.000
Zone * Week	3280.278	24	136.678	3.110	.000
Error	296915.061	6756	43.948		
Total	339701.670	6797			
Corrected Total	316988.982	6796			
a. R Squared = .063 (Adjusted R Squared = .058)					

Normal distribution for locomotion residual



Main effects

Zone

Proportion of comfort behaviour * Outdoor zone				
Proportion of comfort behaviour				
Outdoor zone	Mean	N	Std. Deviation	Std. Error of Mean
Apron	3.3990	2843	9.13411	.17131
Enriched	1.0087	2576	4.90346	.09661
Outer range	.1185	1378	1.94132	.05230
Total	1.8280	6797	6.82960	.08284

Pairwise Comparisons						
Dependent Variable: Proportion of comfort behaviour						
(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound
Apron	Enriched	1.960[*,b]	.235	.000	1.397	2.523
	Outer range	3.111[*,b]	.288	.000	2.422	3.799
Enriched	Apron	-1.960[*,c]	.235	.000	-2.523	-1.397
	Outer range	1.151[*,b,c]	.327	.001	.368	1.934
Outer range	Apron	-3.111[*,c]	.288	.000	-3.799	-2.422

	Enriched	-1.151*,b,c	.327	.001	-1.934	-.368
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. An estimate of the modified population marginal mean (J).						
c. An estimate of the modified population marginal mean (I).						
d. Adjustment for multiple comparisons: Bonferroni.						

Week of access

Proportion of comfort behaviour * Week of outdoor access				
Proportion of comfort behaviour				
Week of outdoor access	Mean	N	Std. Deviation	Std. Error of Mean
Week1	1.0101	198	4.39080	.31204
Week2	4.6154	208	11.02681	.76457
Week3	3.2000	400	10.00050	.50003
Week4	2.4940	417	7.43663	.36417
Week5	1.8223	439	6.36452	.30376
Week6	2.1329	429	7.16518	.34594
Week7	3.5882	425	9.56025	.46374
Week8	2.3665	462	7.75459	.36078
Week9	.7534	522	4.11275	.18001
Week10	1.5410	597	6.36979	.26070
Week11	.9283	474	4.77652	.21939
Week12	.8527	516	4.41199	.19423
Week13	1.1849	557	5.81767	.24650
Week14	1.4676	586	5.83797	.24116
Week15	1.5843	567	5.99038	.25157
Total	1.8280	6797	6.82960	.08284

Interactions

Zone X Week

ANOVA						
Proportion of comfort behaviour						
Week of outdoor access		Sum of Squares	df	Mean Square	F	Sig.
Week3	Between Groups	64.000	1	64.000	.639	.424
	Within Groups	39840.000	398	100.101		
	Total	39904.000	399			

Week4	Between Groups	1134.235	2	567.118	10.735	.000
	Within Groups	21872.000	414	52.831		
	Total	23006.235	416			
Week5	Between Groups	542.141	2	271.071	6.871	.001
	Within Groups	17200.000	436	39.450		
	Total	17742.141	438			
Week6	Between Groups	412.517	2	206.259	4.075	.018
	Within Groups	21560.909	426	50.612		
	Total	21973.427	428			
Week7	Between Groups	2817.066	2	1408.533	16.541	.000
	Within Groups	35935.875	422	85.156		
	Total	38752.941	424			
Week8	Between Groups	874.177	2	437.088	7.473	.001
	Within Groups	26847.473	459	58.491		
	Total	27721.650	461			
Week9	Between Groups	75.895	2	37.947	2.254	.106
	Within Groups	8736.664	519	16.834		
	Total	8812.559	521			
Week10	Between Groups	2148.074	2	1074.037	28.954	.000
	Within Groups	22034.171	594	37.095		
	Total	24182.245	596			
Week11	Between Groups	271.561	2	135.781	6.079	.002
	Within Groups	10520.000	471	22.335		
	Total	10791.561	473			
Week12	Between Groups	187.196	2	93.598	4.881	.008
	Within Groups	9837.610	513	19.177		
	Total	10024.806	515			
Week13	Between Groups	1172.400	2	586.200	18.404	.000
	Within Groups	17645.553	554	31.851		
	Total	18817.953	556			
Week14	Between Groups	2692.964	2	1346.482	45.521	.000
	Within Groups	17244.920	583	29.580		
	Total	19937.884	585			
Week15	Between Groups	1598.454	2	799.227	24.089	.000
	Within Groups	18712.256	564	33.178		
	Total	20310.710	566			

Multiple Comparisons							
Dependent Variable: Proportion of comfort behaviour							
Bonferroni							
Week of outdoor access	(I) Outdoor zone	(J) Outdoor zone	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Week4	Apron	Enriched	3.20000*	.72685	.000	1.4528	4.9472
		Outer range	4.20000	1.83626	.068	-.2139	8.6139
	Enriched	Apron	-3.20000*	.72685	.000	-4.9472	-1.4528
		Outer range	1.00000	1.83626	1.000	-3.4139	5.4139
	Outer range	Apron	-4.20000	1.83626	.068	-8.6139	.2139
		Enriched	-1.00000	1.83626	1.000	-5.4139	3.4139
Week5	Apron	Enriched	2.00000*	.62809	.005	.4905	3.5095
		Outer range	3.00000*	1.09944	.020	.3578	5.6422
	Enriched	Apron	-2.00000*	.62809	.005	-3.5095	-.4905
		Outer range	1.00000	1.09944	1.000	-1.6422	3.6422
	Outer range	Apron	-3.00000*	1.09944	.020	-5.6422	-.3578
		Enriched	-1.00000	1.09944	1.000	-3.6422	1.6422
Week6	Apron	Enriched	2.02500*	.71142	.014	.3151	3.7349
		Outer range	.71121	1.41362	1.000	-2.6864	4.1088
	Enriched	Apron	-2.02500*	.71142	.014	-3.7349	-.3151
		Outer range	-1.31379	1.41362	1.000	-4.7114	2.0838
	Outer range	Apron	-.71121	1.41362	1.000	-4.1088	2.6864
		Enriched	1.31379	1.41362	1.000	-2.0838	4.7114
Week7	Apron	Enriched	4.97500*	.92280	.000	2.7570	7.1930
		Outer range	6.30000*	1.95756	.004	1.5949	11.0051
	Enriched	Apron	-4.97500*	.92280	.000	-7.1930	-2.7570
		Outer range	1.32500	1.95756	1.000	-3.3801	6.0301
	Outer range	Apron	-6.30000*	1.95756	.004	-11.0051	-1.5949
		Enriched	-1.32500	1.95756	1.000	-6.0301	3.3801
Week8	Apron	Enriched	2.11532*	.76866	.018	.2684	3.9622
		Outer range	3.82386*	1.08772	.001	1.2103	6.4374
	Enriched	Apron	-2.11532*	.76866	.018	-3.9622	-.2684
		Outer range	1.70854	1.08635	.349	-.9017	4.3188
	Outer range	Apron	-3.82386*	1.08772	.001	-6.4374	-1.2103
		Enriched	-1.70854	1.08635	.349	-4.3188	.9017
Week9	Apron	Enriched	.02620	.45774	1.000	-1.0732	1.1256

		Outer range	.79883	.44364	.217	-.2667	1.8643
	Enriched	Apron	-.02620	.45774	1.000	-1.1256	1.0732
		Outer range	.77262	.42649	.212	-.2517	1.7970
	Outer range	Apron	-.79883	.44364	.217	-1.8643	.2667
		Enriched	-.77262	.42649	.212	-1.7970	.2517
Week10	Apron	Enriched	3.91960*	.61058	.000	2.4537	5.3855
		Outer range	4.12060*	.61058	.000	2.6547	5.5865
	Enriched	Apron	-3.91960*	.61058	.000	-5.3855	-2.4537
		Outer range	.20101	.61058	1.000	-1.2649	1.6669
	Outer range	Apron	-4.12060*	.61058	.000	-5.5865	-2.6547
		Enriched	-.20101	.61058	1.000	-1.6669	1.2649
Week11	Apron	Enriched	1.40000*	.47260	.010	.2645	2.5355
		Outer range	1.80000*	.64305	.016	.2550	3.3450
	Enriched	Apron	-1.40000*	.47260	.010	-2.5355	-.2645
		Outer range	.40000	.64305	1.000	-1.1450	1.9450
	Outer range	Apron	-1.80000*	.64305	.016	-3.3450	-.2550
		Enriched	-.40000	.64305	1.000	-1.9450	1.1450
Week12	Apron	Enriched	.94354	.45735	.119	-.1549	2.0420
		Outer range	1.51100*	.49321	.007	.3264	2.6956
	Enriched	Apron	-.94354	.45735	.119	-2.0420	.1549
		Outer range	.56746	.47625	.702	-.5764	1.7114
	Outer range	Apron	-1.51100*	.49321	.007	-2.6956	-.3264
		Enriched	-.56746	.47625	.702	-1.7114	.5764
Week13	Apron	Enriched	2.91228*	.58486	.000	1.5079	4.3167
		Outer range	3.31429*	.59671	.000	1.8814	4.7471
	Enriched	Apron	-2.91228*	.58486	.000	-4.3167	-1.5079
		Outer range	.40201	.57802	1.000	-.9860	1.7900
	Outer range	Apron	-3.31429*	.59671	.000	-4.7471	-1.8814
		Enriched	-.40201	.57802	1.000	-1.7900	.9860
Week14	Apron	Enriched	4.59893*	.55391	.000	3.2690	5.9288
		Outer range	4.59893*	.55324	.000	3.2706	5.9272
	Enriched	Apron	-4.59893*	.55391	.000	-5.9288	-3.2690
		Outer range	.00000	.54455	1.000	-1.3074	1.3074
	Outer range	Apron	-4.59893*	.55324	.000	-5.9272	-3.2706
		Enriched	.00000	.54455	1.000	-1.3074	1.3074
Week15	Apron	Enriched	3.00552*	.60350	.000	1.5564	4.4546
		Outer range	4.07738*	.60281	.000	2.6300	5.5248
	Enriched	Apron	-3.00552*	.60350	.000	-4.4546	-1.5564
		Outer range	1.07186	.57672	.191	-.3129	2.4567

	Outer range	Apron	-4.07738*	.60281	.000	-5.5248	-2.6300
		Enriched	-1.07186	.57672	.191	-2.4567	.3129
*. The mean difference is significant at the 0.05 level.							

Zone X Week

ANOVA						
Proportion of comfort behaviour						
Outdoor zone		Sum of Squares	df	Mean Square	F	Sig.
Apron	Between Groups	5614.590	14	401.042	4.899	.000
	Within Groups	231498.937	2828	81.860		
	Total	237113.527	2842			
Enriched	Between Groups	1517.891	13	116.761	4.953	.000
	Within Groups	60395.206	2562	23.573		
	Total	61913.097	2575			
Outer range	Between Groups	168.621	11	15.329	4.170	.000
	Within Groups	5020.918	1366	3.676		
	Total	5189.538	1377			

Frequency tables to diff and mean values of video vs photographic measures of behaviour

Difference in resting					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.00	1	1.0	1.0	1.0
	-1.00	20	20.0	20.0	21.0
	.00	45	45.0	45.0	66.0
	1.00	34	34.0	34.0	100.0

	Total	100	100.0	100.0	

Difference in appetitive/foraging					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.00	2	2.0	2.0	2.0
	-1.00	28	28.0	28.0	30.0
	.00	49	49.0	49.0	79.0
	1.00	19	19.0	19.0	98.0
	2.00	2	2.0	2.0	100.0
	Total	100	100.0	100.0	

Difference in locomotion					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-2.00	4	4.0	4.0	4.0
	-1.00	27	27.0	27.0	31.0
	.00	38	38.0	38.0	69.0
	1.00	29	29.0	29.0	98.0
	2.00	2	2.0	2.0	100.0
	Total	100	100.0	100.0	

Difference in comfort					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.00	3	3.0	3.0	3.0
	.00	95	95.0	95.0	98.0
	1.00	2	2.0	2.0	100.0
	Total	100	100.0	100.0	

MeanRest					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	5	5.0	5.0	5.0
	.50	12	12.0	12.0	17.0
	1.00	21	21.0	21.0	38.0
	1.50	18	18.0	18.0	56.0
	2.00	10	10.0	10.0	66.0
	2.50	22	22.0	22.0	88.0
	3.00	7	7.0	7.0	95.0
	3.50	1	1.0	1.0	96.0
	4.00	3	3.0	3.0	99.0
	4.50	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

MeanApp					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	8	8.0	8.0	8.0
	.50	18	18.0	18.0	26.0
	1.00	24	24.0	24.0	50.0
	1.50	18	18.0	18.0	68.0
	2.00	17	17.0	17.0	85.0
	2.50	10	10.0	10.0	95.0
	3.00	4	4.0	4.0	99.0
	3.50	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

MeanLoc					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	1	1.0	1.0	1.0
	.50	14	14.0	14.0	15.0

	1.00	15	15.0	15.0	30.0
	1.50	21	21.0	21.0	51.0
	2.00	19	19.0	19.0	70.0
	2.50	12	12.0	12.0	82.0
	3.00	7	7.0	7.0	89.0
	3.50	4	4.0	4.0	93.0
	4.00	2	2.0	2.0	95.0
	4.50	5	5.0	5.0	100.0
	Total	100	100.0	100.0	

MeanComf					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	89	89.0	89.0	89.0
	.50	5	5.0	5.0	94.0
	1.00	6	6.0	6.0	100.0
	Total	100	100.0	100.0	

Correlation tables for Hen number and NND relationships

Correlations			
		NND	HEN
NND	Pearson Correlation	1	-.197**
	Sig. (2-tailed)		.000
	N	2880	2880
HEN	Pearson Correlation	-.197**	1
	Sig. (2-tailed)	.000	
	N	2880	4224
**. Correlation is significant at the 0.01 level (2-tailed).			

Correlations			
		NNDapron	HENapron

NNDapron	Pearson Correlation	1	-.096
	Sig. (2-tailed)		.061
	N	960	384
HENapron	Pearson Correlation	-.096	1
	Sig. (2-tailed)	.061	
	N	384	384

Correlations			
		NNDenriched	HENenriched
NNDenriched	Pearson Correlation	1	.057
	Sig. (2-tailed)		.076
	N	960	960
HENenriched	Pearson Correlation	.057	1
	Sig. (2-tailed)	.076	
	N	960	1536

Correlations			
		NNDouterrange	HENouterrange
NNDouterrange	Pearson Correlation	1	.104**
	Sig. (2-tailed)		.001
	N	960	960
HENouterrange	Pearson Correlation	.104**	1
	Sig. (2-tailed)	.001	
	N	960	2304
**. Correlation is significant at the 0.01 level (2-tailed).			

animals

MDPI

Article

Ranging Behaviour of Commercial Free-Range Laying Hens

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Simple Summary: Commercial free-range production has become a significant sector of the fresh egg market due to legislation banning conventional cages and consumer preference for products perceived as welfare friendly, as access to outdoor range can lead to welfare benefits such as greater freedom of movement and enhanced behavioural opportunities. This study investigated dispersal patterns, feather condition and activity of laying hens in three distinct zones of the range area; the apron area near shed; enriched zone 10–50 m from shed; and outer range beyond 50 m, in six flocks of laying hens under commercial free-range conditions varying in size between 4000 and 24,000 hens. Each flock was visited for four days to record number of hens in each zone, their behaviour, feather condition and nearest neighbour distances (NND), as well as record temperature and relative humidity during the visit. Temperature and relative humidity varied across the study period in line with seasonal variations and influenced the use of range with fewer hens out of shed as temperature fell or relative humidity rose. On average, 12.5% of the hens were observed on the range and most of these hens were recorded in the apron zone as hen density decreased rapidly with increasing distance from the shed. Larger flocks appeared to have a lower proportion of hens on range. The hens used the range more in the early morning followed by a progressive decrease through to early afternoon. The NND was greatest in the outer range and decreased towards the shed. Feather condition was generally good and hens observed in the outer range had the best overall feather condition. Standing, pecking, walking and foraging were the most commonly recorded behaviours and of these, standing occurred most in the apron whereas walking and foraging behaviours were recorded most in the outer range. This study supported the findings of previous studies that reported few hens in the range and greater use of areas closer to the shed in free-range flocks. This study suggests that hens in the outer range engaged more in walking and foraging activities and showed signs of better welfare than those closer to the shed.

Abstract: In this study, the range use and behaviour of laying hens in commercial free-range flocks was explored. Six flocks were each visited on four separate days and data collected from their outdoor area (divided into zones based on distance from shed and available resources). These were: apron (0–10 m from shed normally without cover or other enrichments); enriched belt (10–50 m from shed where resources such as manmade cover, saplings and dust baths were provided); and outer range (beyond 50 m from shed with no cover and mainly grass pasture). Data collection consisted of counting the number of hens in each zone and recording behaviour, feather condition and nearest neighbour distance (NND) of 20 birds per zone on each visit day. In addition, we used techniques derived from ecological surveys to establish four transects perpendicular to the shed, running through the apron, enriched belt and outer range. Number of hens in each 10 m × 10 m quadrat was recorded four times per day as was the temperature and relative humidity of the outer range. On average, 12.5% of hens were found outside. Of these, 5.4% were found in the apron; 4.3% in the enriched zone; and 2.8% were in the outer range. This pattern was supported by data from quadrats, where the density of hens sharply dropped with increasing distance from shed. Consequently, NND was greatest in the outer range, least in the apron and intermediate in the enriched belt. Hens sampled in outer range and enriched belts had better feather condition than those from the apron. Standing, ground pecking, walking and foraging were the most commonly recorded activities with standing and pecking most likely to occur in the apron, and walking and foraging more common in the outer range. Use of the outer range declined with lower temperatures and increasing relative humidity, though use of apron and enriched belt was not affected by variation in these measures. These data support previous findings that outer range areas tend to be under-utilized in commercial free-range flocks and suggest positive relationships between range use, feather condition and increased behavioural opportunities and decline in the use of range in cold and/or damp conditions.

Keywords: ranging behaviour; free-range laying hens; feather condition; enrichment; ecological survey

1. Introduction

Free-range egg production has become popular due to consumer interest in welfare friendly products and the banning of conventional wire cages across the European Union (EU) in January 2012. As a consequence, free-range production approaches 50% of the fresh egg market in the UK [1]. EU Council directive [2] requires that stocking density must not exceed 2500 hens per hectare, which is equivalent to four square metres per bird. A number of quality assurance schemes include further requirements, for example The Royal Society for Prevention of Cruelty to Animals (RSPCA)'s Assured, British Egg Industry Council's Lion Brand and Noble Food's Happy Egg brand stipulate flock sizes of no more than 16,000 birds, and where flocks exceed 6000 hens, the flock should consist of colonies or sub-flocks of no more than 4000 birds. To meet these requirements, commercial free-range systems typically consist of large flocks of up to 16,000 birds, housed in a large permanently built shed in a large field (about six hectares for a 16,000 bird flock).

Several studies have reported limited outdoor use in free-range laying hens [3–7] and this pattern in the use of range may be associated with a number of welfare problems, e.g., feather pecking, cannibalism and parasitic fouling of pasture in the extensively used areas [8–10]. The number of hens found outdoors has been reported to be inversely related to flock size [4,9,11–13] with a smaller fraction of the population using the range in larger flocks. Ranging patterns of hens have also been found to be influenced by strain differences [14], season and/or weather conditions [3,4,15], early outdoor rearing experience [3], age of flock [11,14], pop-hole availability [3,16], light intensity in the shed [3] and presence of keel bone fractures [15]. Overall, tree cover and artificial shelters have been utilized to attract hens into the range [3,5,17]. These resources are thought to also provide additional behavioural opportunities to the hens, though behaviour has tended not to be studied in detail, except for direct and indirect assessment of feather pecking.

Hens are thought to accrue a number of welfare benefits when they use the range [7,18]. Savory [19] reported a link between tree cover availability, use of range and injurious feather pecking. Increased use of the range has also been associated with lower prevalence of injurious feather pecking in free-range laying flocks in a number of studies [10,11,17,20–22]. Nicol *et al*. [17] reported a beneficial effect of increased use of range with hens showing a nine-fold reduction in feather pecking activities when more than 20% of hens used the range on sunny days, whilst Bright *et al*. [10] found that feather damage correlated negatively with percentage of canopy cover in end-of-lay hens. They suggested that providing 5% cover within 20–25 m distance from the laying hen house is beneficial to the improvement of feather condition and that injurious feather pecking was reduced when a higher proportion of hens use the range.

This study further explored the ranging behaviour of free-range laying hens. Whilst previous studies have tended to focus on flock level measures of condition and use of outdoor areas, this study aimed to provide a more detailed assessment of dispersal and behavioural patterns. The outdoor area was divided into 3 zones based on proximity to shed and available resources. These were: apron (0–10 m from shed normally without cover or other enrichments); enriched belt (10–50 m from shed where resources such as cover, trees, bushes or saplings and dust-baths were provided); and outer range (beyond 50 m from shed with no cover and mainly grass pasture). The feather condition, NND and behaviour of the hens in different outdoor areas were sampled to determine the impact of location on these parameters. In addition, this study used line transects (a technique derived from ecological census) as a further means of measuring hen numbers and dispersal patterns in the three outdoor zones. We predicted that there would be a decline in the number of hens per unit area with distance from shed and that increasing flock size would reduce range use as found in previous work. This study aimed to provide evidence on how these two factors interacted and the differences in behaviour, dispersal patterns and feather condition between zones.

2. Materials and Methods

2.1. Animals and Management

This study was approved by the University of Lincoln's College of Science Ethics Committee and was carried out using six flocks of commercial laying hens at four farms in Lincolnshire. All six flocks supplied the Happy Egg Company established by Noble Foods UK Ltd. (Oxford, UK). The study population consisted of medium hybrid lines commonly used in egg production: three flocks of Hyline and three flocks of Lohmann Brown hens, with population sizes ranging from 3900 to 23,548 birds and aged between 27 and 55 weeks of age.

Continuous lighting was provided in the sheds for a minimum of eight hours each day and the hens had daytime access to the outdoor range at twenty weeks of age through the pop holes measuring 45 cm × 2 m, located on the two sides of the sheds. There was at least one pop hole per six hundred hens usually opened at 9:00 a.m. each morning and closed at dusk (4:00 p.m. to 6:00 p.m. during the study). The hens were provided with range enrichments and trees to comply with specification of Happy Egg Company. In addition to complying with the requirements of the EU Council Directive [2], the hens in this system had access to additional resources (activity kits) outside the shed and were the same on each farm, comprising of one set of mini shelter, dust bath and a perch per 4000 hens in the outdoor area. Trees were planted between the distance of 10 m and 50 m from the sheds, with the majority of manmade structures located 15–35 m away from the shed. These resources were thought to encourage hens to utilize the outdoor area by providing shelter and increasing behavioural opportunities, though at the time of study the trees were saplings, so canopy cover was limited.

The study was completed between November 2011 and February 2012. Each flock was visited on four different occasions (*i.e.*, each flock was visited four times before another flock was visited) for data collection giving a total of twenty-four sample visits for the study. At least a 48-hour gap was allowed between farm visits to comply with Noble Food's bio-security requirements.

2.2. Sampling Areas

On first arrival, each flock was surveyed for key environmental features including location of shed within field, field boundaries, location and number of pop-holes and the distribution of outdoor resources. Bamboo poles (1 m in height) were then used to divide the outdoor area into zones and to produce 4 lines of transects running perpendicular to the shed. Pilot studies for previous studies [23] had indicated that whilst these poles provide a short term point of interest to hens when initially placed in the ground, the hens rapidly habituated to their presence and the poles had no influence on hens' location after half an hour. Poles were placed in pairs, every 10 m from the shed for 110 m to indicate the quadrats. This had the effect of firstly providing sighting lines parallel to the shed to allow the distance from the shed to be estimated. They also produced the line transect from the edge of shed to 110 m that was made up of eleven 10 m × 10 m quadrats. Where sheds were located centrally in fields and had over 100 m on either side, then two transects were arranged on either side of the shed. Where the sheds were on the edge of the field, with all or most useable area on one side, all four transects were arranged on that side.

Outdoor areas of commercial free-range systems often have features that can be used to differentiate discrete zones located at specific distances from the shed and with different enrichment resources. In this study we defined three discrete zones whose features were common across all the six flocks. These were the apron, enriched and outer range zones. The apron zone was defined as the area between 0 m to 10 m from the shed. There were no additional enrichment resources in this area and no tree cover. Ground vegetation was sparse, with soil, slats, concrete or pebbles covering most of the area. This constituted on average 4.1% of the available outdoor area. The enriched belt covered the area between 10–50 m from the shed and manmade enrichments were located in this area with natural cover in the form of plantations of tree saplings. Ground vegetation varied from low grass pasture, with patches of taller perennial plants such as nettle and patches of bare earth, particularly where the hens had formed scrapes or dust baths. This constituted on the average 21.2% of the available outdoor area. The outer range was defined as the outdoor area 50 m and beyond from the shed and this was the largest part of the outdoor area spanning from the end of the enriched zone to the field boundaries and covered on average 74.7% of available outdoor area. This area mainly consisted of grass pasture, which tended to have low sward during the study period. The boundary for all flocks was 2 m tall electrified wire fence to prevent hens leaving field and deter ground predators from entering the enclosure.

2.3. Data Collection

A general head count was conducted around 12:00 p.m. to determine the total number of hens outdoors in each flock. This involved a brisk walk of the flocks to count the number of hens in apron, enriched and outer range zones, which were combined to provide the estimate for the entire flock. These were used to calculate the percentage of the flock in each area based on farm records of flock size at time of survey. Furthermore, the population density could be calculated in terms of hens per square metre and range area per hen in apron, enriched belt and outer range.

Hen numbers and distribution across zones was also recorded using ecological census techniques utilized by Cooper and Hodges [23]. This was conducted by counting the hens in each quadrat of each transect four times during each visit. Head counts were carried out at 10:00 a.m., 11:00 a.m., 1:00 p.m. and 2:00 p.m. and during the counts, the potential observer influence associated with head counts was minimized by maintaining a distance of 15 meters from the hens. In addition to heads counts, twenty hens were sampled in each zone for NND, feather condition and behaviour. Where there were less than twenty hens in a quadrat, all the hens were sampled. The hen closest to the observer and every second hen was sampled and their immediate activity was categorized using an ethogram of 17 mutually exclusive behaviours ([24], Table 1).

A visual assessment of plumage condition of four different body parts (neck, chest, back and sides) was carried out using a six point scoring scale [25]. In this method, values from 0 (best feathers) to 5 (worst feathers) were assigned to each body parts (see Table 2 for scale values and descriptions) with respect to the degree of damage or no damage to the feathers. The feather condition of the hens was effectively scored from a distance of 5 m to minimize disturbance to the focal animal and flock in general. Bright *et al*. [26] reported a strong positive correlation between feather condition scores recorded from distance and scores from close inspection following capture, which suggests that distance feather scoring techniques are reliable and practical on a commercial scale. Feather scoring and behavioural observations were carried out after the head counts.

Table 1. Ethogram of behaviours under observation (Adapted from Buijs, [24]).

Activity	Description
Standing	Not moving on two feet, body not touching the floor
Sitting	Body and both hocks touching the floor underneath or directly on either side of the bird
Lying	Lying on its side, with both feet on the same side of the bird
Walking	Slow locomotion, the first foot is put down on the floor before the second one is lifted (without pecking or scratching)
Pecking	Pecking on the ground or objects
Foraging	Walking with pecking and scratching
Running	Rapid locomotion, the second foot is lifted before the first is set down
Preening	Moving the beak over the feathers
Feeding	Pecking at the feed in the feeder, or between such pecks
Drinking	Pecking at the drinker, followed by tilting of the head
Shaking	Rapid whole body movement mostly associated with ruffling of the feathers or shaking dust from the plumage
Aggression	Fights including pecking at another chicken
Dust bathing	Foot scratching and bill-raking the litter or lose soil, followed by vertical wing shaking, head rubbing, bill-raking and/or scratching with one leg whilst lying
Stretching	Elongation of the leg not associated with walking
Comfort behaviour	Includes wing flapping, body shaking, feather ruffling and tail wagging but not preening
Head flick	Rapid head movements in horizontal plane
Scratching	Stepping backwards whilst raking the feet across the floor

Table 2. Description of feather scoring method used to evaluate feather condition of the hens (adapted from Bilcik and Keeling, [25]).

Score	Body Feathers	Flight Feathers
0	Intact feathers	Intact feathers
1	Some feathers scruffy up to 3 missing feathers	Few feathers separated but not broken or missing
2	More damaged feathers, greater than 3 feathers missing	A lot of feathers separated and/or a few broken or missing
3	Bald patch <5 cm diameter or <50% of area.	All feather separated, a lot of broken or missing feathers
4	Bald patch >5 cm diameter or greater than 50% of area	Most of feathers missing or broken
5	Completely denuded area	Almost all feathers missing

NND was measured using 1 m poles to mark the locations of the focal bird and its nearest neighbour and the distance measured by running a portable 25 m tape between the poles. The approximate location of chickens and nearest neighbour was noted and measured using measuring tape with the help of a field assistant. This approach was effective at estimating distances to nearest 0.2 m over distances of up to 2 m, but accuracy declined above this distance so distances above 2 m where estimated to the nearest 1 m.

2.4. Weather Measurements

The temperature and relative humidity of sites were measured using a simple indoor/outdoor thermo-hygrometer. Upon arrival, the thermo-hygrometer was positioned in the open outdoor area mid-way between shed and end of range at 2 m above the ground level. The temperature and relative humidity was recorded 4 times per day on each visit at 10:00 a.m., 11:00 a.m., 1:00 p.m. and 2:00 p.m.

2.5. Statistical Analysis

All the data collected was analysed using IBM SPSS 20.0 statistical software (IBM Corporation, Armonk, NY, USA). Temperature and relative humidity data met requirements of parametric statistics, so the effects of time of day were assessed using general linear model analysis of variance (GLM ANOVA) with time of day as fixed factor and flock as a random factor. The average measure of temperature and relative humidity for each visit day was then used to investigate the effect of these measures on total number of hens out of shed. We had planned to investigate the effects of flock size, age and strain as factors in the analysis, however, as it was not possible to balance these between flocks (See Table 3), we instead treated flock identity as a random factor across all analysis.

Table 3. Flocks and their characteristics including strain, number of hens at time of study and age in weeks. Means for % of flock out of shed, hens per quadrat and feather score are reported for each flock.

Farm	Strain of Hens	Size at Time of Study	Age (Weeks)	% of Flock Out of Shed	Hens per Quad	Feather Score
1	Hyline	3900	55	35.1 ± 3.8 [a]	9.8 ± 0.5 [a]	0.14 ± 0.01 [a]
2	Hyline	7300	48	20.1 ± 2.4 [b]	8.1 ± 0.5 [b]	0.21 ± 0.01 [b]
2	Hyline	15,573	27	6.3 ± 0.8 [c]	5.3 ± 0.4 [d]	0.24 ± 0.01 [c]
3	Lohmann Brown	15,470	49	4.6 ± 1.1 [c,d]	6.6 ± 0.4 [c]	0.24 ± 0.01 [c]
4	Lohmann Brown	15,797	51	8.8 ± 0.7 [c]	6.7 ± 0.4 [c]	0.25 ± 0.01 [c]
4 *	Lohmann Brown	23,548	52	3.0 ± 0.5 [d]	5.1 ± 0.4 [d]	0.23 ± 0.01 [c]

[a,b,c,d] Means within a column with different superscripts differ significantly ($p < 0.05$); * Single shed housing two flocks of approximately 12,000 birds each.

GLM analysis was performed on the quadrat distribution data to determine if the fixed factors (zone and time of the day) had influence on the distribution of the hens. Flock identity was treated as a random factor whereas age, strain, flock size, temperature, and relative humidity were fitted as covariates. As there were a number of potential explanatory variables used in the analysis, a step-wise model simplification process was carried out. The residual of the model used in the analysis was found to be normally distributed using a histogram and therefore no data transformation was required before analysis.

NND data was also analysed using GLM approach. A separate model was developed using a similar step-wise simplification procedure as the hen distribution to determine if the location of hens influenced their distances away from the nearest hens. In this model, zone was fitted as a fixed factor and flock was treated as a random factor.

Feather scores from four key body parts (head, neck, chest and back) were explored for descriptive statistics and a GLM analysis was carried out to determine if there was a relationship between feather condition of the hens and the outdoor zone they were found. A fitted feather score model was achieved using a similar approach as in the above analysis.

Behavioural data were explored for descriptive statistics to determine the relative abundance of each of the behaviours recorded. The results of the descriptive analysis revealed that some of the behaviours were not recorded at all or rare and for this reason, only the major behaviours were analysed further using GLM. A step-wise model simplification process was also carried out as in the models above to determine the influence of the zones on the behaviours.

The means and standard error of means for the estimates of distribution, feather scores, NND, behavioural occurrence, temperature and relative humidity are presented in the result section of this article. Further *post hoc* tests were carried out on all the significant variables and interactions in each model using Bonferroni correction factor to determine the pairs that were significantly different from each other.

3. Results

3.1. Weather

Average temperature sampled on visits was 8.56 ± 0.42 °C (range from 0.00 °C to 17.5 °C), and the relative humidity was on average 72.6 ± 1.5% (range from 42.0% to 99.0%). The temperature and relatively humidity varied across the study period, broadly in line with seasonal variations and consequently there was significant variation in both temperature ($F_5 = 4.95$, $p < 0.001$) and relative humidity ($F_5 = 3.38$, $p = 0.008$) between flocks. There was no effect of time of day on either temperature or relative humidity.

3.2. Number of Hens Outdoors and Their Distribution

The mean number of hens out of shed was 1142 ± 91 which represented an average 12.5% of the flock. An average head count of 530 ± 37 was found for the apron area near the shed (5.4% of flock), whereas 401 ± 51 hens were recorded in the enriched belt (4.3%), and 211 ± 44 hens (or 2.8% of flocks) were recorded in the outer range. As the majority of the outdoor area was the outer range, with apron and enriched belts only covering about a quarter of available outdoor area, these resulted in considerable variation in stocking density between the three areas. There were on average 0.31 hens/m^2 on the apron (equivalent to 3.23 m^2 per hen), compared with 0.048 hens/m^2 in the enriched belt (or 20.8 m^2 per hen) and 0.0086 hens/m^2 of outer range giving on average 116 m^2 per hen. There was a significant difference between flocks in percentage of hens on the range ($F_5 = 20.1$, $p < 0.001$), which varied from 35.1% in the smallest flock to 3.0% in the largest flock (Table 3).

3.3. Number of Hens in the Quadrats

The distribution of hens across quadrats was influenced by the time of day ($F_3 = 63.97$, $p < 0.05$) with the greatest number of hens outside at 10:00 a.m. (Figure 1). Outdoor use decreased significantly through the day but showed similar number of hens between 1:00 p.m. and 2:00 p.m. There were more hens in the apron area least in the outer range and intermediate in the enriched zone at all the time periods (Table 4: $F_6 = 30.59$, $p < 0.05$).

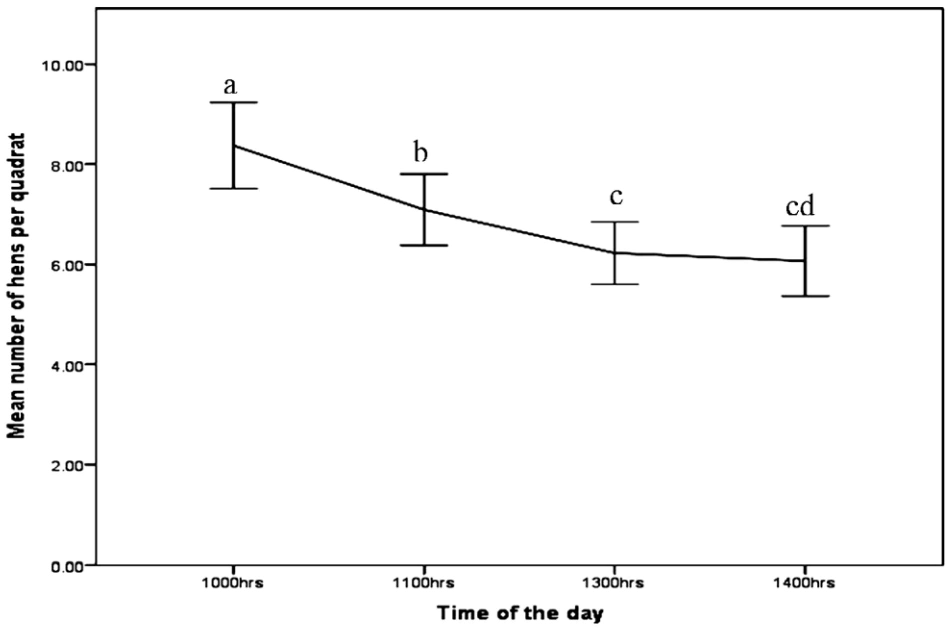

Figure 1. The means of number of hens (±SE) recorded at different times of the day. [a,b,c,d] Means of times with different superscripts are significantly different ($p < 0.05$).

Table 4. Mean numbers of hens in the apron, enriched belt and outer range areas for all the time periods.

	Zones				
Time of the Day	**Apron**	**Enriched**	**Range**	**F-Value**	**SEM**
10:00 a.m.	41.49 [a]	9.97 [b]	1.79 [c]	834.76	0.36
11:00 a.m.	29.98 [a]	9.31 [b]	1.79 [c]	460.67	0.35
1:00 p.m.	24.35 [a]	8.27 [b]	1.83 [c]	340.77	0.33
2:00 p.m.	27.67 [a]	8.31 [b]	0.97 [c]	402.67	0.35

[a,b,c] Means within rows with different superscripts are significantly different ($p < 0.05$).

The counts of hens in the quadrats that made up the line transects were consistent with the findings of the overall head counts, with numbers falling with distance from shed ($F_2 = 352$, $p < 0.001$; Figure 2). Quadrat 1, which included the apron, had an average of 30.87 $\pm$ 0.44 hens, quadrats 2 to 5 in the enriched belt had on average 8.97 $\pm$ 0.22 hens, whilst quadrats 6–11 in the outer range had a mean of 1.60 $\pm$ 0.18 hens per 100 m^2 quadrant. These counts equated to about 3.24 m^2 per hen in the apron quadrats, 11.1 m^2 per hen in the quadrats from the enriched belt and 62.6 m^2 per hen in the outer range quadrats. There was also an effect of flock ($F_5 = 29.1$, $p < 0.001$), with smaller flocks having higher numbers of hens per quadrat than larger flocks (Table 3).

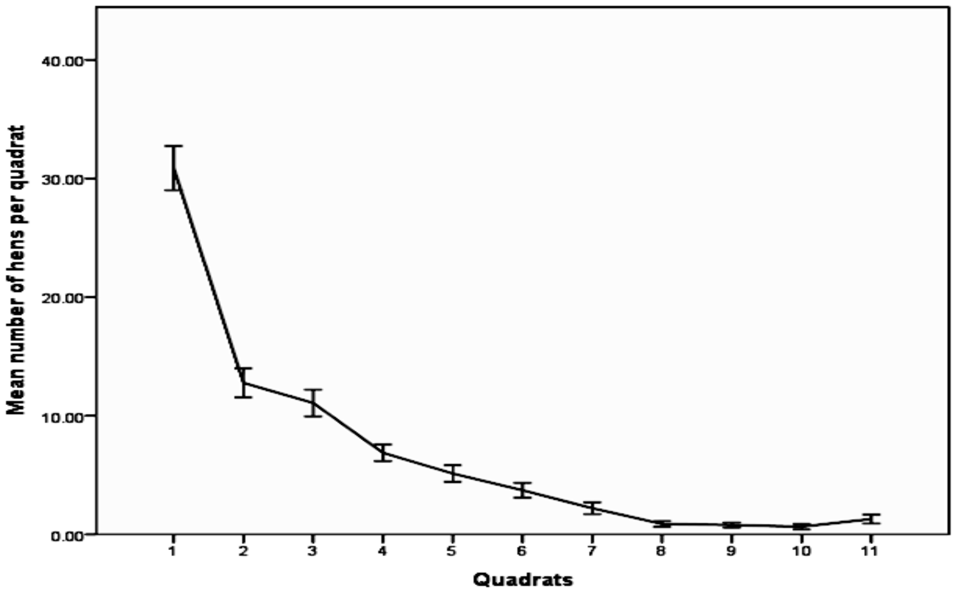

Figure 2. The mean ($\pm$SE) number of hens per 100 m^2 quadrat from first quadrat on apron, through enriched belt (2–5) and outer range (6–11) showing sharp decline in numbers with distance from shed.

There was an effect of temperature on the number of hens per quadrat ($F_1 = 3.02$, $p < 0.001$) with more hens as temperature rose. There was however, no overall effect of relative humidity ($F_1 = 3.02$, $p > 0.05$) on outdoor use.

3.4. Nearest Neighbour Distance

The NND of hens outdoors and was found to differ between the zones ($F_2 = 435$, $p < 0.001$). NND was found to be greatest in the outer range (5.67 $\pm$ 0.15), least in the apron (1.62 $\pm$ 0.05) and intermediate in the enriched belt (2.40 $\pm$ 0.08) so distance between hens increased with increasing distance from the shed (Table 5). There was no effect of flock on the NND ($F_5 = 2.69$, $p > 0.05$).

Table 5. NND and feather condition for hens in apron, enriched belt and outer range.

	Zones				
NND	**Apron**	**Enriched**	**Range**	**F-Value**	**SEM**
	1.62 ^{a}	**2.40 ^{b}**	**5.67 ^{c}**	**435**	**0.14**
	Feather condition scores				
Neck	1.064 ^{a}	0.610 ^{b}	0.154 ^{c}	538.38	0.028
Chest	0.296 ^{a}	0.211 ^{b}	0.070 ^{c}	78.27	0.018
Side	0.006 ^{a}	0.002 ^{a,b}	0.000 ^{b}	3.52	0.012
Back	0.213 ^{a}	0.014 ^{b}	0.007 ^{b}	192.83	0.002
Mean feather scores	0.395	0.214	0.058		

^{a,b,c} Means within rows with different superscripts are significantly different ($p < 0.05$).

3.5. Feather Condition of the Hens

The results showed that feather loss was worst in the neck area (0.609 $\pm$ 0.013), followed by chest (0.192 $\pm$ 0.008) and back (0.078 $\pm$ 0.005), with the side having the best condition scores (0.003 $\pm$ 0.001) (F_3 = 1461, $p < 0.001$). *Post hoc* tests revealed that the hens in the range zone had the best overall feather condition whereas apron had poorer feather condition (see Table 5). Feather condition also differed between flocks (F_5 = 12.9, $p < 0.001$; Table 3) with the smallest flock having the best feather condition, followed by second smallest flock and no difference between the four larger flocks.

3.6. Behaviour of the Hens

Standing (24.8% of samples), pecking (19.8%), walking (26.6%) and foraging (20.6%) were the most recorded behaviours, representing over 90% of the overall activity of hens that were sampled. Of the remaining behaviours only preening (3.4%), sitting (2.6%) and ground scratching were found in more than 1% of samples. Running (0.4%), dust-bathing (0.2%), perching (0.1%) and shaking (0.1% of samples) were rarely sampled. The remaining activities in the ethogram including aggression and comfort behaviours such as wing flapping were not recorded.

To provide a measure of the effect of location on the relative abundance of each activity we compared the incidence of the most common activities in each zone. The results of the relative occurrence of these behaviours in different zones are presented in Table 6. The results showed that standing behaviour differed between the three zones (F_2 = 52.9, $p < 0.001$) and was recorded most in the apron zone. Pecking behaviour was less common in the outer range than in the other zones (F_2 = 24.3, $p < 0.001$). Walking (F_2 = 14.4, $p < 0.001$) and foraging (F_2 = 53.6, $p < 0.001$) activities occurred most in the outer range zone with mean difference between the zones being significant. There was no effect of flock on behavioural measures.

Table 6. The mean occurrence of the four most recorded behaviours (from each daily sample of 20).

Behavioural States	Apron	Enriched	Range	F-Value	SEM
Standing	16.6 ^{a}	8.9 ^{b}	4.2 ^{c}	52.87	0.61
Pecking	9.5 ^{a}	10.9 ^{a}	3.4 ^{b}	24.27	0.57
Walking	9.2 ^{a}	8.3 ^{a}	13.2 ^{b}	14.40	0.49
Foraging	1.7 ^{a}	7.1 ^{b}	15.8 ^{c}	53.63	0.68

^{a,b,c} Means within rows with different superscripts are significantly different.

4. Discussion

The findings of the present study were broadly in line with other research in commercial free-range layer systems regarding range use, in particular that population density declines with distance from shed (e.g., [5,16,17]) and that a lower proportion of the flock are found outdoors as flock size increased (e.g., [4,12,13]). This study also found evidence for a positive relationship between good range use and feather condition (e.g., [17,21,22]) and reduced general range use in colder (e.g., [3,4,15]). The novel sampling methods and additional measures used in this study provided more detailed data on the use of range as well as the relationship between range use, behaviour and feather condition.

The total head count showed that 12.5% of the hens in the sampled flocks were found outdoors at noon. In this study, we did not directly assess the effect of flock size in our analysis due to confounding effects of other flock variables such as age and strain. Nevertheless the variation in both total percentage of the hens counted out of shed and the number of hens counted using quadrat approach suggests that as flock size increased, the use of ranging areas decreased and this is consistent with the findings of a number of other studies [4,9,11–13]. It may have been more demanding for hens in larger flocks to come out of the shed because of the number of hens they will encounter before accessing the outdoor area. In addition, hens in larger flocks require bigger sheds and this will mean that they will walk longer distance to access the range.

Most of the hens found outdoors were recorded in the apron zone and the preference for a closer proximity could be an anti-predator strategy as suggested by Nagle and Glatz [5]. They reported more hens in the range (including the farther areas) when shelterbelts were provided, and suggested these provided shelter from predation [6,27] though shelter from wind, rain or direct sunshine would also be a benefit. Hegelund *et al*. [4] also observed that artificial cover attracted more hens into the range and away from the immediate strips of the shed. The work of Zeltner and Hirt [28] supported the findings of this study and showed that hens were less likely to use the range when no overhead cover was provided. The trees planted in the outdoor range of the flocks used for this study were mainly saplings, which did not provide high levels of cover for the hens. Previous work [23] suggests that although saplings can increase range use, full or nearly full canopy cover has greatest impact on the range use.

It is worth noting that in this study, there were differences between the hen densities derived from head counts and those from the quadrats for the outer range and enriched belt, but not the apron. The head counts of hens out of shed gave an estimate of 0.31 hens/m^2 of which is equivalent to 31.0 hens per 100 m^2 of apron, and similar to the average of 30.9 calculated from quadrat counts. In contrast, twice as many hens were recorded in the enriched belt (9.0 compared with 4.8 based on data from entire enriched belt) and outer range (1.6 hens compared with 0.9 across entire outer range) using the quadrat method compared to general head counts. This suggests that the area covered by the line transects in the enriched belt and outer range were more attractive than other areas of enriched belt and outer range zones. This may simply be a matter of ease of access, in that transects were in line with the sides of sheds where most pop holes would be located or because of the movement of the observer along the transect lines during observations which has the potential to attract more hens to this area compared to the less frequently walked areas of the range.

Alternatively, the higher hen density recorded in the quadrat counts may be related to the specific enrichments provided in these locations e.g., the young tree plantations found across the entire enriched belt, the sampled areas were also the locations of the activity kits provided as part of the Happy Egg Companies flock requirements. These normally consisted of covered dust baths, perch and mini-shelters with one set of kits per 4000 hens, and may have provided additional shelter or behavioural opportunities to attract birds compared to young trees alone. A more detailed study of the impact of additional manmade enrichments and their locations on hen movement would be able to differentiate between these two explanations.

The hens used the range most in the morning but the number of hens outdoors dropped as the day progressed. The interaction between zone and time of the day showed that the hens used the apron most at all times. This study supports other findings [4,5,15] where free-range hens were reported to use the outdoor run most in the morning and evening. In the present study, the hens were observed between 10:00 a.m. to 2:00 p.m. and because of this, the use of range beyond the time was not assessed. The differences in atmospheric conditions across the day may explain why the hens prefer to range more in the morning (e.g., Nicol *et al*. [17]), however in this study, although temperature did affect numbers hens sampled, these factors did not consistently vary with time across the sampling days.

Alternatively, the higher numbers at 10:00 a.m. may reflect high numbers of hens using range resources soon after pop-hole opening at 9:00 a.m.

There was a relationship with general distribution of hens and of the two weather variables measured; higher temperature had largely positive effect on the numbers counted in quadrats, whereas negative impact of relative humidity that would be predicted from other studies was found in this study. Hegelund *et al*. [4] reported a parabolic relationship between temperature and number of hens in the range and they showed that range use increased up to a maximum temperature of 17 °C then a corresponding decrease in range use at temperatures greater than 17 °C. The maximum recorded temperature for this study was 17.5 °C and appeared to encourage more hens to range. Gilani *et al*. [3] reported a similar range use pattern and evidence from their work found that more hens ranged away from the sheds when the relative humidity level was low, on cooler days and with low rainfall. Hegelund *et al*. [4] also reported that wet and rainy conditions had negative influence on the use of range. These findings point to the potential importance of shelter to protect from adverse weather.

The results suggested that location of the hens affected their behaviour. The most commonly recorded activities were standing, pecking, walking and foraging. Comparison of the number of hens engaged in each of these behaviour indicated that standing and pecking were most often observed in the hens found in the apron area, and that walking and foraging were commonly observed in the outer range. The latter may be a reflection of the availability of the large, open space of the outer range and the distance hens would travel to search for resources in the outer range. In contrast the apron provided relatively little additional environmental resources but was close to the indoor environment so required little movement. It is also noteworthy that no aggressive behaviour was recorded in any of the hens sampled, suggesting this behaviour was rare outside of the shed environment. This study did not sample behaviour inside the shed, which may have provided greater potential to detect incidences of feather pecking and aggression due to higher stocking density and different resource availability.

The results indicated that the NND increased as you go away from the shed. The hens showed the least NND in the apron, greatest in the outer range zone and intermediate in the enriched belt. Based on the results of the total and quadrat head counts, apron zone had the greatest number of hens and covered less than a quarter of the available outdoor area, thereby making it the most densely populated outdoor zone. As the number of hens dropped from the shed, there was more usable space available to individual hens (decreased stocking density), which in turn resulted in the increasing NND recorded in this study. The hens in the outer range may have moved to this area to avoid aggression or competition for the resources in the zones near the shed and may have preferred to maintain greater distances from other hens to avoid such aversive experiences.

The results of feather score analysis showed that the sides had the most intact feathers and neck had the most damaged feathers. There was an effect of flock on feather condition with the two smallest flocks having significantly better feather scores than the four larger flocks. Before drawing too strong a conclusion from this, it is worth noting that only six flocks were included in this study, that they represented a relatively restricted age range (five flocks between 48 and 55 weeks of age and one flock of 27 weeks), and that the feather condition of the hens was generally very good. Normally feather condition would be expected to decline with age, and a larger number of flocks covering a greater age range would be expected to find a significant age effect. Nevertheless, the better feather condition associated with smaller flocks in this study that made more use of the outside environment is noteworthy.

Hens in the outer range zone had the best feathers (in all body parts) whereas apron recorded the worst feathers. The feather condition of hens in the enriched zone was better than those found in the apron but worse than their counterparts in the outer range zone. Although we found some variation in plumage, overall feather condition was excellent and many hens in outer range, enriched and apron zones showed no evidence of feather damage. Bilcik and Keeling [25] suggested that ease of feather removal and the ease of access to different parts of the body may have resulted in specific feathers being attractive targets for pecking in laying hens; they have been reported to prefer shorter semi-plumes than longer ones [29]. Wing feathers have stronger shaft and are longer than the neck feathers, which may have resulted in less damages recorded in the wing feathers. High concentration of birds and greater pecking activities in the apron may have resulted in the poor feather quality of hens in this area. Range zone offered more foraging opportunities and hens in this zone foraged more and had better chances of avoiding competitive locations. Huber-Eicher and Wechsler [30] reported an inverse relationship between feather pecking and foraging behaviour in laying hens and in the present study, more hens in the range zone performed foraging behaviour at greater NND, which may have resulted in less feather damage recorded for the hens found in this area.

5. Conclusions

These data supports previous studies that reported few hens in the outer range of free-range flocks. Hens that range further from shed were, however, more likely to be engaged in walking and foraging, compared to more sedate birds in the apron and enriched area, and generally had better feather condition. These findings suggest hens that make use of outer range have better welfare than those that remain close to the shed and the direction of any causal relationships warrants further investigation. For example, better feathered hens may be more likely to use range because they find it less aversive than other hens, or their feather condition may be improved because of spending more time out on range. Similarly, hens may travel to outer range because they are actively seeking opportunities to engage in activities such as foraging, or they may tend to naturally disperse further from sheds, and exhibit more foraging in response to the cues they encounter once they reach the outer range.

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